CALIFORNIA FISH AND GAME

"CONSERVATION THROUGH EDUCATION"

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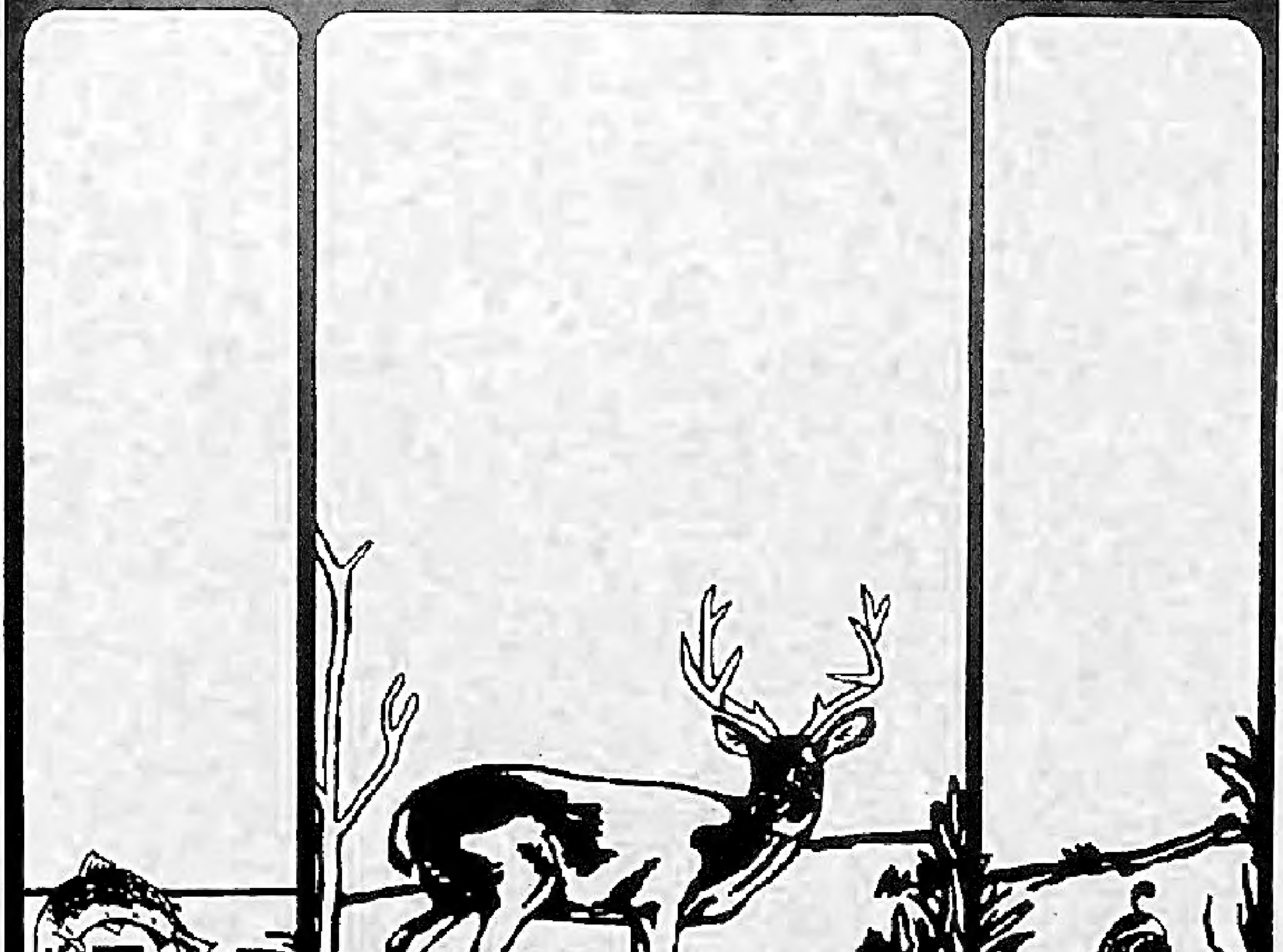

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SETTING PRIORITIES FOR NATIVE FISH CONSERVATION: AN EXAMPLE FROM THE SOUTH YUBA RIVER WATERSHED

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This study examined the fish species composition and abundance in tributaries of the South Yuba River and how priorities for conservation of native fish can be established among tributaries. Most of the tributaries were dominated by rainbow trout, *Oncorhynchus mykiss*, while California roach, *Lavinia symmetricus*, were only found in one tributary, Kentucky Ravine. Priorities should consider numbers and abundance of natives, species composition, ownership, and watershed disturbance.

INTRODUCTION

The South Yuba River flows through the heart of the area impacted by the California Gold Rush that began in 1849. In the 19th century, hydraulic mining severely impacted the watershed, as millions of tons of rock, gravel, and other debris were flushed down the river (Palmer and Vileisis 1993). Hillsides were denuded of trees and other vegetation both by mining and by large populations of miners seeking wood and other materials for subsistence. Some resident native fishes persisted through this extreme alteration of the landscape, although runs of anadromous fishes (Chinook salmon, *Oncorhynchus tshawytscha*; steelhead trout, *Oncorhynchus mykiss*; and Pacific lamprey, *Lampetra tridentata*) were extirpated by sediment loads from mining and then excluded from recolonizing the watershed by dams constructed to collect mining debris.

Today, the landscape still shows the effects of mining, including large hydraulic mining pits that are now part of Malakoff Diggins State Park in the Humbug Creek drainage. In the 125 plus years since hydraulic mining was halted, most of the watershed has become revegetated and most of the streams now contain fish populations[3,4]. However, the old hydraulic mining ditches now carry water for urban use, reducing flows in both tributaries and mainstem, and most tributaries have check dams in their upper reaches that create ponds, into which non-native fishes have been introduced[4].

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[4] Randall, P.J. 1997. Distribution and ecology of fish and frogs in tributaries to the South Yuba River. Master's thesis. University of California, Davis.

A statewide system of aquatic habitats managed for biodiversity (Aquatic Diversity Management Areas (ADMA)) has been proposed as a means of stemming the decline of native California fish species (Moyle and Yoshiyama 1994). Schlosser (1991) stressed the importance of considering the entire drainage, through the use of landscape ecology principles, in conserving stream fishes. South Yuba River tributaries play vital roles in sustaining native fish populations in the South Yuba River watershed by providing a refuge for California roach, *Lavinia symmetricus*, and temperature refugia and juvenile rearing habitat for rainbow trout, *Oncorhynchus mykiss*[3]. Limited available funding for aquatic conservation in the South Yuba River watershed makes it necessary to set priorities for conservation of fish in these tributaries.

In this study, we surveyed tributaries of the lower reaches of the South Yuba, where mining had the most severe impacts, to answer the following questions: 1) what native species have persisted and, conversely, which expected native species are absent in tributaries of the South Yuba River; 2) what are the impacts of non-native fishes, which typically are most successful in highly disturbed environments; and 3) what tributary streams should have the highest priority for protection and restoration. The answers to these questions should have fairly broad interest because the South Yuba ecosystem has been recovering on its own, largely by benign neglect, since hydraulic mining was banned. Examination of this system may provide insights into the potential for long-term recovery of other regions impacted by mining and other human activities.

STUDY AREA

The South Yuba River is located on the western slope of the Sierra Nevada, in the Sacramento River basin. The study area, located near Nevada City, comprised tributaries of the lowermost 38 km of the South Yuba River (165-701 m above sea level).

Tributaries within the study area include Missouri Canyon, Humbug Creek, Spring Creek, Rock Creek, Augustine Creek, Rush Creek, Shady Creek, Owl Creek, French Corral Creek, and Kentucky Ravine (Figure 1). French Corral Creek and some sections of Shady Creek have intermittent flows, with isolated pools remaining during the summer, while the remaining streams have perennial flows. There are small impoundments, which serve as sources of invading non-native species, on Humbug, Spring, Rock, Rush, and Owl creeks and Kentucky Ravine[4]. Humbug, Spring, and Shady creeks have been significantly affected by sediment loads from historical hydraulic mining, with other creeks to a lesser extent. Siltation in stream channels may also have impacted some sections of Kentucky Ravine, French Corral, and Owl creeks as the result of intense wildfires in 1989 and subsequent soil erosion. Waterfalls or steep cascades are present in a majority of the tributaries in the study area just upstream of their confluence with the South Yuba River. Only two of the tributaries sampled (Kentucky Ravine and Rush Creek) have more than 300 m of low to moderate gradient, accessible habitat suitable for most native fishes of the South Yuba River.

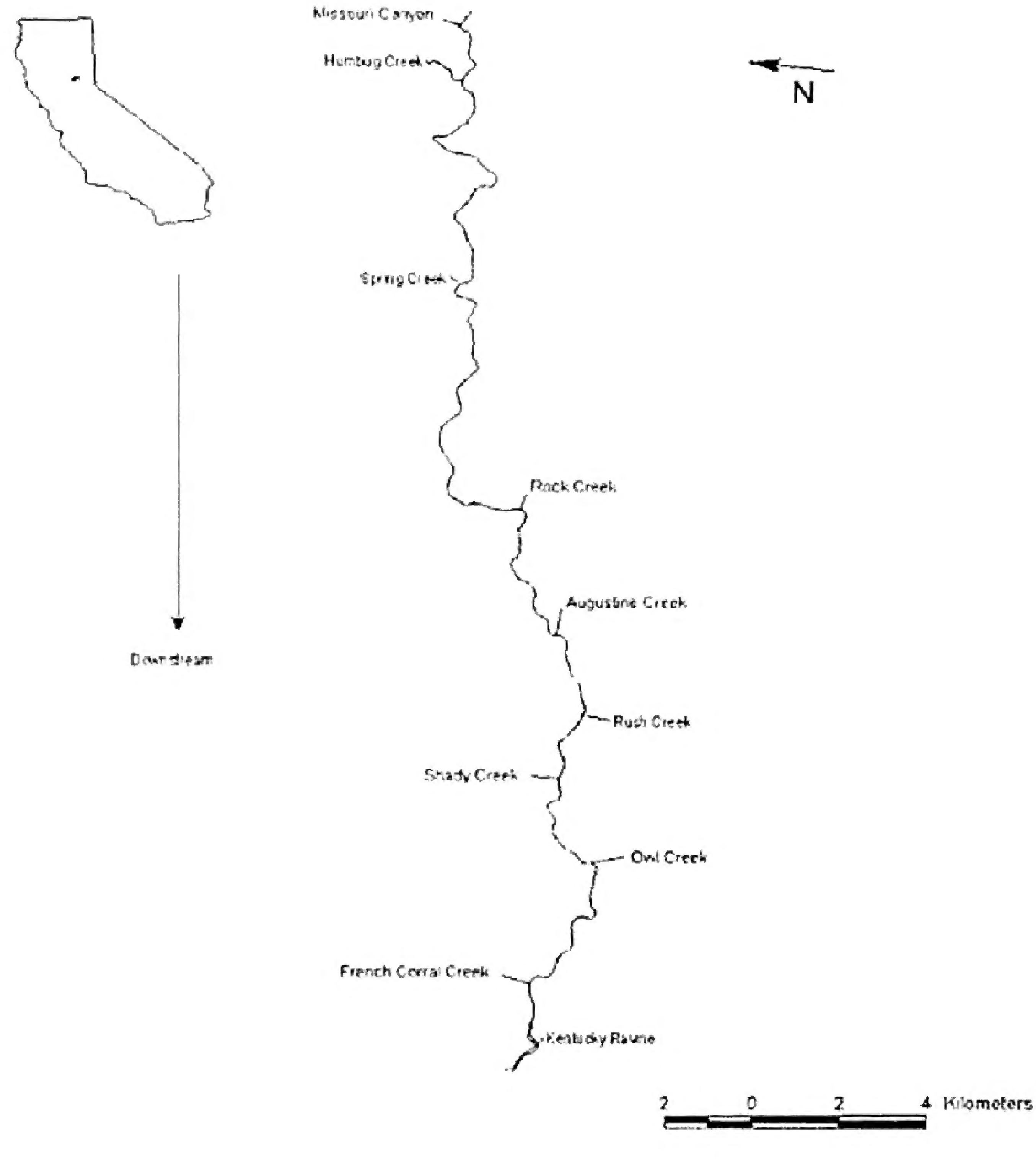

Figure 1. Map of South Yuba River tributaries.

METHODS

Field studies were conducted on South Yuba River tributaries during the summers of 1991, 1992, 1993, 1995, and 1996 (Table 1). The species composition of tributaries of the South Yuba River was determined in 1991 and 1992 by single-pass electrofishing. Specifically, Spring Creek, Missouri Canyon, and Humbug Creek were sampled in 1991, and Rush Creek and Kentucky Ravine were sampled in 1992. All sampling was

Table 1. Sampling of tributaries. Definition of table entries: 1 = sampled with one-pass electrofishing, 3 = sampled with three-pass electrofishing. Blank table entries indicate that the tributary was not sampled in that year.

Tributary Name	1991	1992	1993	1995	1996
Missouri Canyon	1		3		
Humbug Creek	1		3	1	1
Spring Creek	1		3	1	1
Rock Creek			3	1	1
Augustine Creek				1	1
Rush Creek		1	3	1	1
Shady Creek				1	1
Owl Creek			3	1	1
French Corral Creek			3	1	1
Kentucky Ravine		1	3	3	3

conducted within 200 m of the confluence of each tributary with the South Yuba River. Fish caught were identified, and their standard length (SL) to the nearest mm and, in some cases, their weight to the nearest 0.1 g measured.

In 1993, the species composition and the total number and biomass of fish was determined for the tributaries sampled in 1991 or 1992, plus French Corral, Rock, and Owl creeks, using the Leslie catch per unit effort method (Van Den Avyle 1993). After subjectively selecting what appeared to be a representative section of the tributary, generally around 50 m in length, near its confluence with the South Yuba River, block nets were placed at the top and bottom of the section. Three passes were made through the section with electrofishing equipment. At the end of each pass, each fish caught was identified, its SL and weight measured, and then was released outside of the section. Afterwards, the length, several widths (used to estimate the average width), and maximum depth of each section were measured, and the percentage of habitat types (run, riffle, and pool) within each section visually estimated. Glides were not present in the tributaries. Habitat types were delineated using Morhardt's habitat-typing system[5]. Pools were defined as having a maximum depth greater than 0.3 m and an average velocity of less than 0.3 m/s. Riffles were defined as having a maximum depth less than 0.3 m and an average velocity of greater than 0.3 m/s. Runs were defined as having a maximum depth greater than 0.3 m and an average velocity of greater than 0.3 m/s.

In 1995 and 1996, the species composition of fish was determined for Shady and Augustine creeks and the tributaries sampled in 1993 except for Missouri Canyon. Sections were sampled near the confluence of the tributaries with the South Yuba River, as in 1991-1993, and also further up (1 to 7 km above the confluence of the tributaries with the South Yuba River) in the watersheds of all sampled tributaries, except

[5] Morhardt, J.E., D.F. Hanson and P.J. Coulston. 1983. Instream flow analysis: increased accuracy using habitat mapping. Pages 1294-1304 *in:* Waterpower 83: an international conference of hydropower. Tennessee Valley Authority, Norris, Tennessee.

Augustine Creek. At confluence and upstream sites, sections, averaging 44 m in length, were selected to include representative riffle, run, and pool habitats. All tributaries were sampled with one-pass electrofishing, with the exception of the lower portion of Kentucky Ravine, which was sampled in a 100-m section with three-pass electrofishing as in 1993. All fish caught were identified and measured (SL) and then released back into the stream. The same physical variables were measured as in 1993.

Seven impoundments (farm ponds) in the drainages of three tributaries (Kentucky Ravine, and Rock and Rush creeks) were sampled in 1996 using 9- and 15-m seines, as well as a 15-m gill net. Other drainages had ponds but were not sampled due to access issues. Pond margins were typically dense with aquatic vegetation or very steep, making sampling for all age classes of fish difficult. Typically the smaller fish in the margins were captured, but the larger fish were able to escape. When gill nets were used, they were set in the deepest section of the pond and left for 2-3 hours. Fish were identified and measured (SL).

For the three-pass electrofishing data collected in 1993 and in lower Kentucky Ravine in 1995 and 1996, effort for each pass was defined as the number of minutes spent electrofishing, while catch was the total number or weight of fish caught in the pass. Simple linear regression (Wilkinson 1990) was used to estimate the total biomass and number of fish in each section as the value of the cumulative catch corresponding to a value of zero for catch per unit effort. The number and biomass of rainbow trout were calculated as the product of the total number or biomass and the percentage of rainbow trout of the total fish or biomass captured. For tributaries where the regression was not statistically significant at the $p = 0.05$ level for the biomass estimate, the biomass for each species was estimated by multiplying the calculated number of fish by the average weight of the fish caught for that species. Length-frequency distributions of rainbow trout were constructed for each tributary to identify year classes.

The following variables were selected to use in ranking the tributaries to set priorities for conservation of native fish in these tributaries, using the data collected in 1993: 1) biomass of rainbow trout; 2) number of rainbow trout; 3) total biomass of all native fish; and 4) total number of all native fish. Ranking of South Yuba River tributaries by numbers and biomass of native species is appropriate, since management of Class III ADMAs (areas, such as the South Yuba River watershed, which have been extensively and largely irreversibly modified by human activities despite their natural appearance) would focus on species or habitat types, rather than ecosystems (Moyle and Sato 1991). Numbers and biomass were selected because they would be expected to be correlated with, respectively, recruitment and survival. Rainbow trout were selected because they were the dominant species in most of the tributaries, while total native fish represent all of the native fish present.

The decision whether to use fish density, rather than numbers or biomass, to address effects of the amount of habitat sampled, was based on the statistical significance at the $p = 0.05$ level of the relationships between the above fish variables and the following section dimension variables: 1) length; 2) surface area; and 3) volume (simple linear regression, [Wilkinson 1990]). A principal components analysis (Wilkinson 1990) was performed, using the correlation matrix of the four fish variables, to rank the

tributaries, based on the score on the first principal component. The purpose of the principal components analysis was to collapse the four fish variables into one measure (the first principal component), which could then be used to rank the tributaries.

RESULTS

The species found in the lower portions of the tributaries were rainbow trout; Sacramento pikeminnow, *Ptychocheilus grandis*; hardhead, *Mylopharodon conocephalus*; Sacramento sucker, *Catostomus occidentalis*; California roach; green sunfish, *Lepomis cyanellus*; bluegill, *Lepomis macrochirus*; smallmouth bass, *Micropterus dolomieui*; and brown trout, *Salmo trutta* (Table 2). The same species were found in the upper portions of the tributaries except hardhead were missing and largemouth bass, *Micropterus salmoides*, and brown bullhead, *Ictalurus nebulosus* were also present. Compared to the upper portions of the tributaries, farm ponds lacked rainbow trout, California roach, and smallmouth bass, but also contained Sacramento perch, *Archoplites interruptus*; golden shiner, *Notemigonus crysoleucas*; fathead minnow, *Pimephales promelas*; and mosquitofish, *Gambusia affinis* (Table 3).

No adult fish of any species were found in any of the tributaries. Most of the lower portions of the tributaries had primarily young-of-year and juvenile rainbow trout. Low numbers of juveniles of other native species and introduced fish species were present in some tributaries (Table 2). In contrast, an isolated pool in French Corral Creek only had green sunfish and bluegill, and the fish species composition of Kentucky Ravine was largely introduced and native warm-water fishes (Table 2). California roach were only found in Kentucky Ravine; roach were much more abundant in 1993 than in 1992, and were even more abundant in 1995 and 1996 (97-117 fish in 100 m) than in 1993 (69 fish in 130 m). Based on length-frequency histograms, most of the rainbow trout in

Table 2. Relative abundance and distribution of fish species in South Yuba River tributaries. Definition of abundance categories: A = abundant (> 30 % of fish present); C = common (10 to 30 % of fish present); F = few (< 10 % of fish present); R = rare (< 1 % of fish or only one individual observed); N = not present in some years; blank = never present. Entries with multiple categories indicate that the abundance varied with year. YOY fish are rainbow trout less than 100 mm. Juvenile fish are < 250 mm for pikeminnow, sucker, hardhead, and smallmouth bass, and are 100-200 mm for rainbow trout.

a. Native Fish Species

Stream	Reach	Rainbow trout YOY	Rainbow trout Juvenile	Sacramento sucker Juvenile	Sacramento pikeminnow Juvenile	Hardhead Juvenile	CA Roach
Missouri Canyon	Lower	A					
Humbug Creek	Upper	A	A				
Humbug Creek	Lower	A	R/A	R/N	R/N		
Spring Creek	Upper	A	A				

Stream	Reach	Rainbow trout YOY	Rainbow trout Juvenile	Sacramento sucker Juvenile	Sacramento pikeminnow Juvenile	Hardhead Juvenile	CA Roach
Spring Creek	Lower	A	F/N				
Rock Creek	Upper	A	A				
Rock Creek	Lower	A	N/A	C/R	F/N		
Augustine Creek	Lower	A					
Rush Creek	Upper	A	A				
Rush Creek	Middle	A	A	F			
Rush Creek	Lower	A/F	F/C	F/A	F/N		
Shady Creek	Upper						
Shady Creek	Lower		A				
Owl Creek	Upper		F				
Owl Creek	Middle		F	F			
Owl Creek	Lower	A/C	F/A	C/A	F/N		
French Corral Cr	Upper						
French Corral Cr	Lower						
Kentucky Ravine	Upper	R	F	F	R		A
Kentucky Ravine	Lower	R/F	N/F	C/A	F/C	F/N	A/F

b. Introduced Fish Species

Stream	Reach	Green sunfish	Bluegill	Large-mouth bass	Small-mouth bass Juvenile	Brown bullhead	Brown trout
Missouri Canyon	Lower						
Humbug Creek	Upper						
Humbug Creek	Lower	N/R					
Spring Creek	Upper						
Spring Creek	Lower						
Rock Creek	Upper	C		R			R
Rock Creek	Lower						R/N
Augustine Creek	Lower						
Rush Creek	Upper	A	R				
Rush Creek	Middle	F					
Rush Creek	Lower						
Shady Creek	Upper				A		
Shady Creek	Lower						
Owl Creek	Upper	A		A		C	
Owl Creek	Middle		R/N				
Owl Creek	Lower		R/N				
French Corral Cr	Upper	A	A				
French Corral Cr	Lower	R/N	A				
Kentucky Ravine	Upper	C	F	R			
Kentucky Ravine	Lower	C/R			F		N/R

Table 3. Fish species present in ponds. Definition of table entries: P = fish species was present in one or more ponds in that tributary; blank = fish species was absent from ponds sampled in that tributary.

Species	Kentucky Ravine	Rock Creek	Rush Creek
Sacramento pikeminnow	P		
Sacramento sucker	P		
Sacramento perch	P		
Green sunfish	P	P	P
Bluegill	P	P	P
Largemouth bass	P	P	P
Brown trout		P	
Brown bullhead	P		
Golden shiner	P		
Fathead minnow		P	
Mosquitofish	P		P

tributaries were young-of-year, although some of the tributaries (Table 2) had some larger rainbow trout (up to 192 mm SL). The largest populations of Sacramento suckers, representing multiple age classes, were found in Kentucky Ravine and Rush Creek, the only two tributaries in the study area that have moderate gradients which allow suckers to access upstream areas. Bluegill, largemouth bass and green sunfish were the most abundant fishes found in pond habitats and the most abundant non-native fishes in the stream sites.

The species composition of tributaries was consistent from year to year for abundant species, but varied for less common species. For those cases where species were found in the lower portion of a tributary in 1993 but not in 1995 or 1996, that species was few or rare in 1993. In addition, the introduced fish species not found in the lower portions of tributaries in 1995 and 1996 were usually present farther upstream in those tributaries.

For most of the tributaries, there was a good fit of the data to the expected linear relationship between catch per unit effort and cumulative biomass or numbers for the three-pass electrofishing sampling; all of the regressions were statistically significant, with the exception of biomass for Owl and French Corral creeks. Since the only significant section-size relationship was for rainbow trout biomass and section volume ($r^2 = 0.58$), density for rainbow trout biomass was computed by dividing by section volume density, while density was not used for the other three fish variables. The first principal component of the four ranking criteria for South Yuba tributaries (Table 4) explained 84% of the total variance of these four criteria. Owl and Rock creeks ranked the highest, while Missouri Canyon and Spring Creek ranked the next highest, and French Corral Creek (with no native fish) ranked the lowest (Table 4).

Table 4. Ranking of South Yuba tributaries based on number, weight, and density of native fishes. Units of rainbow trout numbers and all native species numbers are number of fish. Units of rainbow trout biomass density [Wt/Vol] are g/m^3. Units of all native fish biomass [Weight] are g. PC Score is the score of the first principal component for the four ranking criteria (rainbow trout and all native fish biomass and numbers). All native species includes rainbow trout, Sacramento suckers, Sacramento pikeminnow, hardhead, and California roach.

	Rainbow trout		All Native Species		
Tributary Name	Number	Wt/vol.	Number	Weight	PC Score
Owl Creek	138	14.5	165	1,887	3.97
Rush Creek	97	6.6	104	372	1.00
Missouri Canyon	78	3.7	78	79	0.05
Spring Creek	18	10.2	18	551	- 0.04
Humbug Creek	16	3.5	17	387	- 0.87
Rock Creek	12	3.8	19	81	- 1.11
Kentucky Ravine	1	0.7	44	246	- 1.16
French Corral Cr	0	0.0	0	0	- 1.84
Eigenvector for first PC	0.49	0.51	0.50	0.51	

DISCUSSION

The distribution and range of native fishes in the study area was highly variable among tributaries and appeared to be most affected by physical barriers. Sacramento pikeminnow and hardhead, present, except for Kentucky Ravine, at only the lower sites in, respectively, five and one tributaries, had the smallest range within each tributary in which they were present. These species apparently were limited by steep gradients at the mouth of each tributary, with the exception of Kentucky Ravine and Rush Creek. California roach were limited to the lowest 3 km of Kentucky Ravine because of barriers at the upper end as well as by predation from non-native fishes in the South Yuba River[3]. Sacramento sucker were able to invade steeper gradients in Rush and Owl creeks, and thus were present at the middle sites in these tributaries, but were generally limited in range because of barriers. However, rainbow trout were observed at both upper and lower sites for most of the drainages. Trout have most likely been introduced into the upper reaches of these drainages and have since colonized most of the habitats above the barriers.

Distribution of non-native fishes was also not limited by barriers or stream gradient, but were more associated with the proximity of ponds. Pond fishes most likely enter the stream system during high flow events, and stream reaches closer to these ponds have a greater chance of being invaded. Bluegill, largemouth bass and green sunfish were the most abundant fishes found in pond habitats and the most abundant non-native fishes in the stream sites.

Green sunfish are the most widespread non-native fish because they are more adapted to stream environments (Moyle and Nichols 1973). A wide range of age classes in the stream sites indicates green sunfish may persist through high spring flows and successfully reproduce in stream environments. As a result, green sunfish may pose a long term threat of competition and predation on the native fish. The absence of native fish from French Corral Creek was probably due in part to negative effects of sunfish. In other intermittent streams with isolated pools, sunfish have replaced California roach, which could otherwise survive the low dissolved oxygen levels and high temperatures typical of isolated pools (Moyle 2002).

Bluegill, brown bullhead, and largemouth bass were less widespread and less abundant in stream habitats than green sunfish, and were limited to slow moving stream habitats and deep pools in steep gradient sections just below ponds. These three species are not well adapted to stream environments with fluctuating flows and probably occur in streams as the result of washdown from upstream ponds. Similarly, the non-native mosquitofish, fathead minnow, and golden shiner were present in ponds, but not found in streams because they are not adapted to fastwater habitats.

Brown trout and smallmouth bass are better adapted to stream habitats with fluctuating flows (Moyle 2002), but were less widespread in the tributaries, apparently because of their absence from ponds, except for one pond containing brown trout. Smallmouth bass occur in the lower mainstem but appear unable to invade the steeper tributaries. Although the relatively low number of native fish in the lower portion of Rock Creek (Table 4) may be due to predation by brown trout, they are less of a concern than introduced centrarchids due to their low numbers.

The extent to which non-native fishes affect the native fish community may entirely depend on the invader. A good example of how different introduced species invade the native assemblage is demonstrated in Kentucky Ravine. This tributary has several farm ponds in the headwaters providing a constant source of bluegill, largemouth bass, and green sunfish which are found with four native species throughout the lower 3 km of stream. However, the green sunfish had multiple age classes, ranging from 30-120 mm SL, while bluegill consisted of only young-of-the-year, ranging from 50-80 mm SL. All age classes of both these species were found in the upstream ponds. This discrepancy in age class structure may indicate successful breeding and colonization of stream habitats by green sunfish and a corresponding lack of success of colonization by the bluegill.

Monitoring of the distribution and abundance of fish species is important in evaluating the effectiveness of and altering other management actions. At a minimum, annual electrofishing of Kentucky Ravine would show whether or not introduced species were having adverse effects on California roach populations, potentially requiring installation of fish barriers in Kentucky Ravine near its confluence with the South Yuba River and eradication of introduced fish from Kentucky Ravine and nearby impoundments. While the abundance of California roach in Kentucky Ravine increased through the period of this study, further monitoring would be needed to determine if this trend will continue. Multiple years of monitoring data are also needed to accurately

determine the species composition of tributaries, since, as shown in this study, less common species may be missed with only one year of data.

The conservation of native fishes in the South Yuba River watershed would be enhanced by protecting the biotic integrity of at least some of these tributaries through either the acquisition of land adjacent to these tributaries or conservation easements for such land. The elimination of introduced fish species from impoundments on South Yuba River tributaries, through draining or the use of rotenone, would also enhance the conservation of native fish in these tributaries. Limited available funding for aquatic conservation in the South Yuba River watershed makes it necessary to set priorities for conservation of fish in these tributaries.

Despite its low PC score (Table 4), Kentucky Ravine should have the highest priority for protection, since it is the only place where we found California roach in the South Yuba River watershed and also contained all other native species. Owl and Rush creeks are the next most important tributaries, since they can serve as temperature refugia for rainbow trout when water temperatures in the lower portions of the South Yuba River exceed 28 °C; this probably explains why these tributaries have the highest densities of rainbow trout. Missouri Canyon and Spring Creek would have the next highest priority based on number and biomass of native fish, while the other tributaries would have a relatively low priority for the conservation of native fish.

The use of principal components analysis in rankings streams can aid in resolving differences between ranking criteria, such as the higher ranking of Missouri Canyon for numbers versus the higher ranking of Spring Creek for biomass. While ranking of streams can be a valuable tool in setting priorities for conservation of native species, the ranking should not be used blindly, but must be considered within the context of the species present in the streams. In this case, using only the ranking of tributaries based on the principle components analysis would have resulted in Kentucky Ravine having a low priority, despite the importance of Kentucky Ravine as habitat for California roach. California roach are a priority for conservation in the South Yuba River watershed due to their restricted distribution.

Consideration of factors in addition to native fish densities could result in different priorities for conservation of South Yuba River tributaries. For example, Spring, Rush, and Humbug creeks might have a higher priority for conservation due to the presence of native foothill yellow-legged frogs, *Rana boylii*[4]. Further, Rush Creek might have a higher priority for conservation because of the 1.5 km of low-gradient habitat present in the lowermost portion. Based on the above factors, Rush Creek might have a higher priority for conservation than Owl Creek, despite its lower ranking. Humbug Creek might have a higher priority for conservation than indicated by the ranking in Table 4, since it would have a greater potential for restoration because it is primarily in State Parks jurisdiction. Conversely, Spring Creek might have a lower priority for conservation because the watershed is primarily private land, and because current mining operations still have impacts on the Creek[4]. Accordingly, setting conservation priorities requires an ecosystem approach so that all organisms and habitats of concern are given appropriate consideration.

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HABITAT SELECTION BY FEMALE NORTHERN PINTAILS WINTERING IN THE GRASSLAND ECOLOGICAL AREA, CALIFORNIA

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To determine relative importance of habitats available in the Grassland Ecological Area (GEA) to wintering female northern pintails, *Anas acuta*, we studied habitat use relative to availability (i.e., habitat selection) in the GEA during September through March, 1991-94 for 196 Hatch-Year (HY) and 221 After-Hatch-Year (AHY) female pintails that were radio tagged during August - early October in the GEA (n = 239), other San Joaquin Valley areas (n = 132), or other Central Valley areas (n = 46). Habitat availability and use varied among seasons and years, but pintails always selected shallow and, except on hunting days, open habitats. Swamp timothy, *Heleochloa schoenoides*, marsh was the most available, used, and selected habitat. Watergrass, *Echinochloa crusgalli*, marsh in the GEA was used less than available at night in contrast to previous studies in other SJV areas. Preferred late-winter habitats were apparently lacking in the GEA, at least relative to in the Sacramento Valley and Delta where most pintails moved to in December each year. Impacts on pintails of the increasing practice of managing marshes for increased emergent vegetation to attract other species should be monitored. Shallow, open habitats that produce seeds and invertebrates available to pintails in late winter would help maintain pintail abundance in the GEA.

INTRODUCTION

Current abundance of breeding northern pintails, *Anas acuta*, in North America is near the historic lows of the early 1990s (U.S. Fish and Wildlife Service and Canadian Wildlife Service[1] 2002) and pintail abundance in California during winter is only about 25% of that during the 1970s (U.S. Fish and Wildlife Service, Portland, Oregon, USA,

[1]U. S. Fish and Wildlife Service and Canadian Wildlife Service. 2002. Waterfowl population status, 2002. U.S. Fish and Wildlife Service, Washington, D.C., USA.

unpublished data). Because wintering habitats may affect survival (Fleskes[2] 1999) and productivity of pintails (Raveling and Heitmeyer 1989), effective pintail management requires a thorough understanding of their winter habitat selection. This is especially important in the Central Valley, where over 90% of natural wetland habitat has been lost, yet about half of pintails in North America still winter (Gilmer et al. 1982, Austin and Miller 1995).

The need to intensively manage waterfowl habitats is especially crucial in the Grassland Ecological Area (GEA) in the northern part of the San Joaquin Valley (SJV). Although the GEA is the largest contiguous block of wetland habitat remaining in the Central Valley (Heitmeyer et al. 1989), in contrast to Central Valley areas to the north, where winter-flooded rice and grain fields maintain many of the same functions as wetlands they replaced (Elphick 2000), most crop fields in the northern SJV are plowed after harvest and left dry. Thus, waterfowl wintering in the northern SJV must rely almost entirely upon wetland resources within the GEA (Fleskes et al. 2002*a*).

Pintails wintering in California spend most of their time resting and feeding (Miller 1985). Pintails loaf during the daytime throughout the wintering period (i.e., August - March), but before hunting season they feed extensively during both daytime and night to replenish fat reserves depleted by breeding and fall migration (Miller 1985, 1986). During hunting season, most feeding is done at night and loafing is the main daytime activity (Euliss[3] 1984, Miller 1985). Daytime feeding increases again after the hunting season as pintails prepare for spring migration and nesting. Thus, habitat use at night mainly reflects feeding site selection, daytime use during hunting season mainly reflects loafing site selection, and daytime use before and after hunting season reflects both feeding and loafing site selection.

Information on habitat use and selection by pintails in the GEA is lacking. Surveys (Isola et al. 2000, California Department of Fish and Game, Los Banos, California, USA, unpublished data) provide some information on general habitat use, but no areas were surveyed at night. Food habits of pintails collected at Los Banos Wildlife Area (WA) (Beam and Gruenhagen[4] 1980, Connelly and Chesemore 1980) provide some insight into habitat use on that area, but most pintails fly to private duck clubs at night (Fleskes et al. 2002*a*) and data on habitat selection throughout the GEA are lacking. To provide information for wetland habitat managers, we studied habitat use by female northern pintails relative to availability (i.e., selection) in the GEA during September through March, 1991-94. Our goals were to determine day and night habitat use and selection before, during, and after hunting season, to identify the relative importance of roosting

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[2]Fleskes, J. P. 1999. Ecology of female northern pintails during winter in the San Joaquin Valley, California. Dissertation, Oregon State University, Corvallis, Oregon, USA.

[3]Euliss, N. H., Jr. 1984. The feeding ecology of pintail and green-winged teal wintering on Kern National Wildlife Refuge. Thesis, Humboldt State University, Arcata, California, USA.

[4]Beam, J., and N. Gruenhagen. 1980. Feeding ecology of pintails (*Anas acuta*) wintering on the Los Banos Wildlife Area, Merced County, California. California Department of Fish and Game, Federal Aid Wildlife Restoration Progress Report, Project W-40-D-1.

and feeding habitats for pintails in the GEA and test the null hypothesis that use of each habitat would equal its availability.

STUDY AREA

Habitat in the GEA was composed mainly of seasonal (≤23,313 ha) and semipermanent-permanent marsh (≤1,160 ha) with other flooded areas including San Luis Reservoir and forebay (6,300 ha), sewer (≤245 ha) and evaporation ponds (≤39 ha), and flooded agricultural lands (≤1,572 ha) (Fleskes[2] 1999). Excluding the San Luis Reservoir and forebay, 75% of the habitat flooded before hunting season and 82% thereafter was privately-owned (Fleskes et al. 2002a). Some public areas were completely open to hunting (Volta, Salt Slough, and China Island WAs) and others included units closed to hunting (Los Banos WA and San Luis, Kesterson, Merced, and Arena Plains National Wildlife Refuges [NWRs], Fig. 1).

Habitat conditions differed before (Prehunt), during (Hunt), and after (Posthunt) waterfowl hunting season. Most marsh was seasonal and was dry during summer except for periodic irrigations to promote seed production of watergrass, *Echinochloa crusgalli*, swamp timothy, *Heleochloa schoenoides*, pricklegrass, *Crypsis niliaca*, (a species similar to swamp timothy), and other wetland plants. These marshes were usually filled with water during Prehunt to be fully flooded by the start of Hunt. Thus, the average amount of flooded marsh was 2-4 times greater during Hunt and Posthunt than during Prehunt. Most flooding of agricultural lands and other uplands within the GEA occurred during late-winter as a result of rain events and stream overflows.

Annual variation in precipitation, water supplies and management affected habitats differently in the GEA (Fleskes[2] 1999). Conditions in the GEA were the driest on record during 1991-92 because continuing drought and resulting low reservoir levels (California Department of Water Resources[5] 1991, National Oceanic and Atmospheric Administration, Asheville, North Carolina, USA, unpublished data) prevented summer irrigation, delayed fall flood-up and greatly reduced water deliveries to private wetlands; water deliveries to public areas were less reduced and allowed nearly normal management and flood-up (Grassland Water District, Los Banos, California, USA, unpublished data). Conditions improved during 1992-93 with above-average precipitation and normal water deliveries to all GEA areas. During 1993-94, conditions improved further when implementation of the Central Valley Project Improvement Act (Davis 1992) nearly doubled the water delivered to the Grassland Water District (Grassland Water District, Los Banos, California, USA, unpublished data) and wetlands on Kesterson NWR and Salt Slough WA were restored. Annual changes in the GEA were most evident for seasonal marsh with the average amount of flooded seasonal marsh present each week increasing during Prehunt from 5,385 to 6,698 to 9,603 ha; during Hunt from 19,358 to 19,915 to 22,713 ha; and during Posthunt from 20,011 to 21,206 to 23,313 ha, in 1991-92,

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[5]California Department of Water Resources. 1991. California's continuing drought, 1987-1991: A summary of impacts and conditions as of December 1, 1991. Sacramento, California, USA.

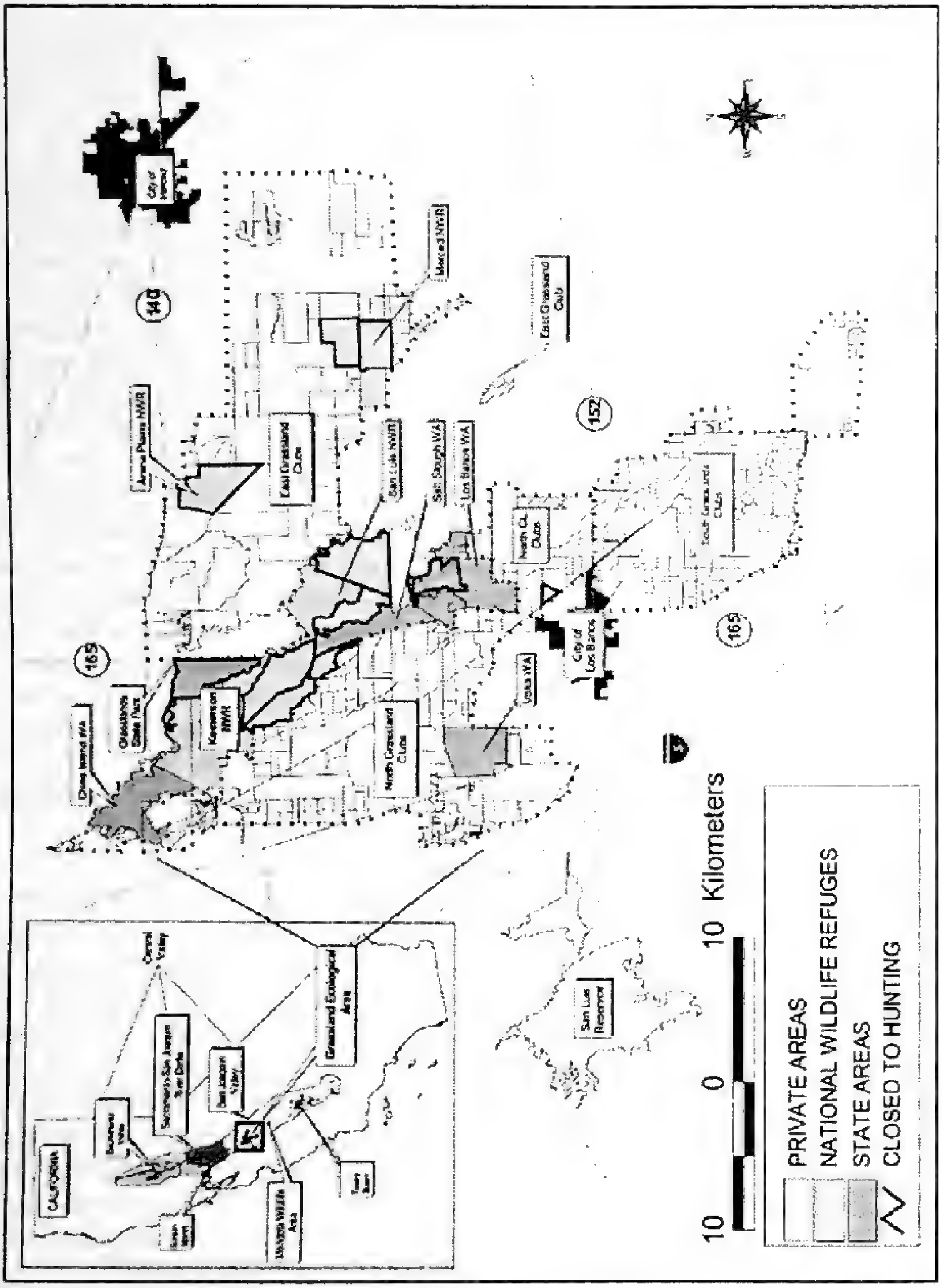

Figure 1. The Grassland Ecological Area (GEA) in the San Joaquin Valley of California's Central Valley. The GEA includes California Department of Fish and Game Wildlife Areas (WAs), U.S. Fish and Wildlife Service National Wildlife Refuges (NWRs), private waterfowl hunting clubs, and San Luis Reservoir. Habitat use and selection by female northern pintails, *Anas acuta*, in the GEA were studied during September - March, 1991-94 for pintails that were radio tagged in the GEA, Mendota WA (50 km southeast of the GEA), the Tulare Basin (150 km southeast of the GEA), and the Suisun Marsh (180 km northwest of the GEA).

1992-93 and 1993-94, respectively (Fleskes[2] 1999). Flooded area of evaporation ponds, sewer ponds, and reservoirs was fairly constant among intervals and years. Study area habitats are described by U.S. Fish and Wildlife Service[6] (1978) and Heitmeyer et al. (1989).

Duck hunting daily bag limits and season lengths remained constant during the study, but the timing of the hunting season (Hunt) varied among years. For 1991, 1992, and 1993, respectively, Hunt was composed of a 22-day first season starting 26, 24, or 23 October, a 12-, 19-, or 27-day closure that split the duck hunting season, and a 37-day second season ending 5, 10, or 16 January (California Department of Fish and Game[7] 1991, California Department of Fish and Game[8] 1992, California Department of Fish and Game[9] 1993). WAs, NWRs, and nearly all duck clubs in the GEA allowed hunting only on Wednesdays, Saturdays, and Sundays during Hunt (hereafter shoot days). We define Posthunt as the interval from end of Hunt to 1 April 1992 and 1993 or 17 March 1994.

METHODS

Classifying Habitat

We observed no pintails using dry lands (except levees, shorelines, islands) in the SJV and considered only flooded areas as habitat. We classified habitats three ways based upon: 1) hydrology and physical characteristics, 2) vegetation composition, and 3) percent emergent cover.

We used U. S. Geological Survey Quadrangles, the San Joaquin Valley Drainage Program Study Team[10] (1990) report, aerial photographs, site visits, and data provided by managers to identify hydrology and physical characteristics and classify eight general habitats: 1) agricultural drainwater evaporation ponds; 2) sewage treatment ponds; 3) deepwater reservoirs and lakes (e.g., San Luis Reservoir, fish-rearing ponds), 4) seasonal marsh, which included vernal pools; 5) semipermanent and permanent

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[6]U. S. Fish and Wildlife Service. 1978. Concept plan for waterfowl wintering habitat preservation, Central Valley, California. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

[7]California Department of Fish and Game. 1991. 1991 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

[8]California Department of Fish and Game. 1992. 1992 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

[9]California Department of Fish and Game. 1993. 1993 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

[10]San Joaquin Valley Drainage Program Study Team. 1990. Fish and wildlife resources and agricultural drainage in the San Joaquin Valley, California. Volume I and II. San Joaquin Valley Drainage Program, Sacramento, California, USA.

marshes, which included marshes, sloughs, shallow lakes, and oxbows that remained at least partially flooded throughout most years; 6) uplands, which included idle grasslands and irrigated pasture; 7) rice (harvested), and 8) other tilled agricultural lands. Each year, we used data provided by wetland managers, interpretation of Natural Resources Conservation Service and our aerial photography, and site visits to further classify marsh based on dominant understory vegetation as: 1) swamp timothy (includes pricklegrass); 2) watergrass (usually associated with sprangletop, *Leptochloa* spp.); and 3) other (e.g., jointgrass, *Paspalum distichum*, spikerush, *Eleocharis macrostachya*, alkali bulrush, *Scirpus robustus*, smartweed, *Polygonum lapthifolium*, etc.,). In addition, we used aerial photographs to classify marsh as "open" (<25% emergent vegetation), or "hemi-closed"($\geq$25% emergent vegetation). We define emergent vegetation as cattail, *Typha* sp., bulrush, *Scirpus* sp., watergrass and any other erect plant that was above water after the area was fully flooded.

Measuring Habitat Availability

To represent the average amount of each habitat type that was available to radio-tagged pintails in the GEA during the multi-week Prehunt, Hunt, and Posthunt intervals (i.e., habitat availability), we weighted weekly estimates of the amount of flooded area of each habitat by the number of pintail locations we obtained that week and then calculated each interval average. First, we entered vegetation and weekly flooding data obtained from managers, aerial photographs, and site visits into a Geographic Information System (GIS) and ARC/INFO (ESRI) computer program. Next, we used the data in the GIS to determine flooded area of each habitat each week in the GEA during August-March, 1991-94. Finally, because the number of radio-tagged pintails present in the GEA changed each week due to emmigration, immigration, and mortality, rather than simply averaging weekly flooding estimates to calculate average flooded area of each habitat for the multi-week Prehunt, Hunt and Posthunt intervals, we instead weighted weekly flooding estimates by the number of pintail locations obtained in the GEA that week and then calculated interval averages. We estimated availability and use for the three multi-week intervals rather than individual weeks because the number of locations we obtained per week for each pintail was inadequate for weekly comparisons of use and availability. Also, although flooding did change somewhat among weeks within intervals (especially as marshes were flooded during Prehunt), flooding and pintail movement patterns (Fleskes et al. 2002a) within intervals were more similar than across intervals.

Measuring Habitat Use

Pintail Capture and Tracking

We periodically pinpointed locations of 417 radio-tagged female pintails to track their habitat use in the GEA during September through late March, 1991-94. We studied GEA habitat use of all 124 HY and 115 AHY pintails that we radio tagged throughout

the GEA (Volta and Los Banos WAs, San Luis and Kesterson NWRs, duck clubs in the south part of the GEA), 36 HY and 53 AHY pintails that we radio tagged in Mendota WA (50 km southeast of the GEA), 13 HY and 30 AHY pintail that we radio tagged in the Tulare Basin (150 km southeast of the GEA), and 24 AHY and 22 HY pintails that Casazza[11] (1995) radio tagged in Suisun Marsh (180 km northwest of the GEA, Fig. 1). Pintails were captured with rocket-nets (Schemnitz 1994) during 29 August - 6 October 1991, 31 August - 5 October 1992, and 28 August - 25 September 1993. Captured pintails were aged (Carney[12] 1992), weighed ($\pm$5 g), measured (flat wing, culmen 1, total tarsus [Dzubin and Cooch[13] 1992]), radio tagged (Dwyer 1972, Pietz et al. 1995), and released at the capture site. All pintails radio tagged in GEA were included in this study but 29 pintails radio tagged at Mendota WA, 19 at Tulare Basin, and 148 at Suisun Marsh did not visit the GEA and were not included in our study.

We scanned the GEA entirely (Gilmer et al. 1981) and determined each pintail's location on $\geq$2 shoot days and following nights and $\geq$2 nonshoot days and following nights each week during Hunt and $\geq$2 days and nights each week during Prehunt and Posthunt. We obtained two bearings from known locations using a vehicle-mounted dual-Yagi null-peak telemetry system (Cochran and Lord 1963) to minimize time between bearings and because preliminary tests showed more bearings did not increase accuracy in our flat, open study areas. We obtained >89% of locations <1.6 km from the bird at 50-130 degree angles. Warnock and Takekawa (1995) reported an average azimuth error of 1.5 degrees and an error polygon of 1.1 ha with location distances 0.5 - 3.0 km using an identical system, which is much smaller than the average size of habitat polygons ($\bar{x}$ = 20.3 ha) in the GEA. We calculated pintail locations using a modified version of XYLOG and UTMTEL (Dodge et al.[14] 1986, Dodge and Steiner 1986). We intersected pintail locations in the GIS with digitized habitat maps to determine habitat for each location.

Habitat Selection Analysis

We used compositional analysis (Aitchison 1986, Aebischer et al. 1993) to examine day and night habitat selection by pintails. We considered all flooded areas in the GEA available for potential use by each pintail in the GEA because all flooding was within the daily pintail flight range from major pintail roost sites in the GEA (Fleskes et al. 2002*a*). We used multivariate analysis of variance (Johnson and Wichern 1982, SAS Institute 1989) to test whether a composition of use-to-availability log ratios differed

[11]Casazza, M L. 1995. Habitat use and movements of northern pintails wintering in the Suisun Marsh, California. Thesis, California State University, Sacramento, California, USA.

[12]Carney, S. M. 1992. Species, age and sex identification of ducks using wing plumage. U.S. Fish and Wildlife Service, Washington, D. C., USA.

[13]Dzubin, A., and E. G. Cooch. 1992. Measurement of geese: general field methods. California Waterfowl Association. Sacramento, California, USA.

[14]Dodge, W. E., D. S. Wilkie, and A. J. Steiner. 1986. UTMTEL: A laptop computer program for location of telemetry Afinds@ using Loran-C. Massachusetts Cooperative Research Unit. Report, U.S. Fish and Wildlife Service.

significantly from zero ($P \leq 0.05$), indicating selection by pintails. When selection was detected, ranks were assigned to each habitat type, means and standard errors for each log-ratio were calculated, and *t*-tests were used to identify significant ($P \leq 0.05$) differences among rankings of habitats (Aebischer et al. 1993). We combined drainwater evaporation and sewage treatment ponds because habitat was similar and use was minimal for both. We compared habitat selection among years (1991-92, 1992-93, 1993-94), shoot and nonshoot days during hunting season, bird age class (HY, AHY), and bird capture mass (above vs. below age-class mean).

RESULTS

General Habitat Use and Selection

During all intervals, seasonal marsh received highest pintail use (Table 1) and was most highly selected (Table 2); deepwater reservoirs and sewage treatment and evaporation ponds received lowest pintail use (Table 1) and were least selected (Table 2). Flooded rice and other agriculture lands were not always available but when available they were selected above all other habitats except seasonal marsh. Permanent-semipermanent marsh ranked higher during the day than at night and was used more than available only on shoot days.

Marsh Types Used and Selected

Swamp timothy marsh received more use by pintails than marshes dominated by watergrass or other plants (Table 1). Pintails selected swamp timothy and avoided watergrass marsh at night and during Prehunt, Posthunt, and nonshoot days during Hunt; marsh without much timothy or watergrass (i.e., other) ranked in the middle (Table 2). Watergrass was selected only on shoot days, when most pintails in GEA roosted in the sanctuary of San Luis NWR (Fleskes et al. 2002a) which included several watergrass fields. In the evening, pintails that had day-roosted on San Luis NWR flew past Salt Slough WA watergrass units on their way to night-feed in timothy marsh on duck clubs (Fleskes et al. 2002a). Pintails selected open over hemi-closed marsh ($t \geq 4.74, P < 0.001$), except on shoot days ($t = 7.13, P < 0.001$).

Selection Relative to Pintail Body Mass and Age

Habitat rankings were nearly identical for HY and AHY pintails. Pintail age appeared as a significant factor in habitat selection models in only two instances when significance levels of the rankings differed by age (Table 2). Habitat selection did not differ among pintails that were lighter or heavier than average at capture.

Table 1. Composition (proportions) of habitat types (evaporation pond [EP], sewer pond [SP], reservoir [RS], upland [UP], rice [RI], other tilled agriculture [AG], permanent-semipermanent marsh [PM], seasonal marsh [SM]), marshes by dominant plant (swamp timothy [T], watergrass [W], other [O]) and habitats (except EP, SP, RS) by emergent cover (<25% open, ≥25% hemi-closed [Hemic]) available (Avail = $\bar{x}$ of weekly proportions weighted by locations) and used by 417 radio-tagged female pintails in Grassland Ecological Area, 1991-94.

	PREHUNT			HUNT			POSTHUNT		
Habitat	Avail	Day Use	Night Use	Avail	Day Use	Night Use	Avail	Day Use	Night Use
EP	0.002	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001
SP	0.011	<0.001	<0.001	0.008	0.005	<0.001	0.008	<0.001	<0.001
RS	0.346	<0.001	<0.001	0.226	0.004	0.001	0.210	0.044	0.048
UP	0.005	0.013	0.006	0.005	0.006	0.014	0.032	0.069	0.089
RI	0	-	-	0.001	<0.001	0.001	0.001	0.004	0.002
AG	0.002	0.002	0.004	0.001	0.005	0.002	0.004	0.034	0.044
PM	0.042	0.020	0.015	0.032	0.078	0.007	0.034	0.013	0.030
SM	0.591	0.966	0.975	0.726	0.900	0.976	0.709	0.834	0.786
T	0.543	0.585	0.639	0.549	0.477	0.632	0.545	0.614	0.534
W	0.116	0.161	0.082	0.099	0.352	0.087	0.102	0.140	0.093
O	0.341	0.253	0.279	0.351	0.170	0.281	0.354	0.246	0.373
Open	0.66	0.71	0.81	0.70	0.63	0.86	0.70	0.78	0.76
Hemic	0.33	0.29	0.19	0.30	0.37	0.14	0.30	0.22	0.24

Table 2. Selection by radio-tagged female northern pintails of flooded habitats (seasonal marsh [SM], rice fields [RI], other tilled agriculture [AG], idle or grazed uplands [UP], semipermanent-permanent marsh [PM], evaporation and sewer ponds [ES], reservoirs [RS]), and marshes (i.e., SM and PM) classified by dominant plant (swamp timothy [T], watergrass [W], other [O]) during prehunt (Pre), hunt (Hnt) and posthunt (Pos) days (D) and nights (N) in Grassland Ecological Area, California, 1991-94.

		Comparison[a]			Rankings[b] of general habitats and marsh type									
Interval	n[c]	Year	Age	Shoot status	SM	RI	AG	UP	PM	ES	RS	T	W	O
PreD	275	Pooled	Pooled	Nonshoot	1A		2B	3C	4D	5DE	6E	1A	3B	2B
	85	91-92	Pooled	Nonshoot	1A		2B	3C	4D	5DE	6E	1A	2B	3B
	89	92-93	Pooled	Nonshoot	1A		2B	3C	4CD	5D	6E	1A	3C	2B
	101	93-94	Pooled	Nonshoot	1A		2B	3B	4B	5B	6B	1A	2B	3B
	137	Pooled	HY	Nonshoot	1A		2B	3C	5D	4D	6E			
	138	Pooled	AHY	Nonshoot	1A		2B	3C	4D	5D	6E			
PreN	274	Pooled	Pooled	Nonshoot	1A		2B	3C	5D	4D	6E	1A	3C	2B
	85	91-92	Pooled	Nonshoot	1A		2B	3C	5D	4D	6E	1A	3B	2A
	88	92-93	Pooled	Nonshoot	1A		2B	3C	4D	5DE	6E	1A	3C	2B
	101	93-94	Pooled	Nonshoot	1A		2B	3B	4B	5B	6C	1A	3C	2B
HntD	365	Pooled	Pooled	Pooled	1A	2B	3C	4D	5E	6F	7G	2B	1A	3C
	100	91-92	Pooled	Pooled	1A	2B	3B	5C	4B	6D	7E	2B	1A	3C
	108	92-93	Pooled	Pooled	1A	2B	4C	5D	3BC	6E	7F	2B	1A	3C
	157	93-94	Pooled	Pooled	1A	3B	2B	5C	4C	6D	7E	2B	1A	3C
	347	Pooled	Pooled	Shoot	1A	2B	4C	5D	3B	6E	7F	2B	1A	3C
	337	Pooled	Pooled	Nonshoot	1A	2B	3B	5C	4C	6E	7F	2B	1A	3C
HntN	348	Pooled	Pooled	Pooled	1A	2B	3C	4D	6F	5E	7G	1A	3C	2B
	96	91-92	Pooled	Pooled	1A	2B	3B	4C	6D	5D	7F	1A	3C	2B
	102	92-93	Pooled	Pooled	1A	2B	3C	4D	6F	5E	7G	1A	3C	2B
	150	93-94	Pooled	Pooled	1A	3B	2B	4C	6E	5D	7F	1A	3C	2B
PosD	75	Pooled	Pooled	Nonshoot	1A	2B	3BC	4C	6E	5E	7F	1A	3C	2B
	16	91-92	Pooled	Nonshoot	1A	4BC	2A	3AB	5CD	6D	7D			
	36	92-93	Pooled	Nonshoot	1A	2B	4B	3B	6C	5C	7D			
	23	93-94	Pooled	Nonshoot	1A	3B	2B	4C	5C	6D	7D			
PosN	71	Pooled	Pooled	Nonshoot	1A	2B	3B	4B	6C	5C	7D	1A	3C	2B
	15	91-92	Pooled	Nonshoot	3AB	4B	2A	1A	5BC	6C	7C			
	32	92-93	Pooled	Nonshoot	1A	2B	4CD	3BC	6E	5DE	7F			
	24	93-94	Pooled	Nonshoot	1A	3B	2B	4C	6C	5C	7C			
	31	Pooled	HY	Nonshoot								1A	3B	2AB
	40	Pooled	AHY	Nonshoot								1A	3C	2B

[a]Comparisons by year, pintail age, or shoot status are listed only when rankings for that variable differed (Wilks= Lambda test, $P < 0.05$); rankings for birds with different body condition did not differ.

[b]Rankings with same letters not different (t-test, $P < 0.05$). Rice not ranked during prehunt because none was flooded.

[c]Number of radio-tagged pintails.

DISCUSSION

Foraging Habitats Selection

Pintails throughout the Central Valley feed primarily on seeds during Prehunt to replenish fat reserves lost during migration but invertebrates comprise a major portion of the diet in spring to provide protein for rapid growth of reproductive organs (Miller 1987). Invertebrates do not comprise a major portion of the pintail diet in the Sacramento Valley until February (Miller 1987) but in the SJV invertebrates make up a major portion of the pintail diet as early as November (Beam and Gruenhagen[4] 1980, Connelly and Chesemore 1980, Euliss[3] 1984). The reason invertebrates were prominent in the pintail diet earlier in the SJV is unknown. However, based upon habitat selection we observed, we speculate that without abundant flooded agriculture like in the Sacramento Valley, pintails (and probably other waterfowl) almost completely relied upon managed marsh habitats and depleted wetland seeds in SJV marshes earlier.

Swamp timothy marsh produces greater biomass of invertebrates than other SJV marsh types (Severson[15] 1987), which may explain why pintails continued their high use of timothy marsh throughout winter. However, pintails immediately selected the only flooded rice fields in the GEA when they became available in November, even though these habitats were farther from sanctuary than all others (Fleskes et al. 2002*a*). In addition, most pintails left the SJV and flew to Sacramento Valley rice fields during early December (Fleskes et al. 2002b). Thus, availability of preferred seeds is apparently a key factor when pintails select feeding habitats but invertebrate availability may become more important as seeds decline or physiological needs change.

In contrast to the low night use of GEA watergrass marsh by pintails that we observed, pintails at Mendota WA (Fleskes[2] 1999) and Kern NWR (Euliss and Harris 1987) used watergrass extensively at night. We speculate two possible reasons for why pintail use of watergrass varies among areas. First, management or structure of watergrass marsh may differ among areas in ways that makes watergrass attractive to foraging pintails in Mendota WA and Kern NWR but not in the GEA. For instance, watergrass fields at Mendota WA were drained earlier than those at Salt Slough WA in the GEA and allowed to dry before reflooding (G. Gerstenberg, California Department of Fish and Game, Los Banos, California, USA, personal communication), resulting in a shorter, less dense stand with seeds that ripen and disperse when reflooded. Alternatively, the level of competition with mallards, *Anas platyrhynchos*, in watergrass marsh may vary among areas and impact use of watergrass marsh by pintails. Pintails are well adapted to feed in timothy marsh, the habitat they normally selected in the GEA. The pintail bill is structured for efficient collection of small seeds (Krapu 1974) and may provide an advantage over larger-billed species, such as mallards for feeding on swamp timothy seeds. However, this advantage for pintails may be lost

[15]Severson, D. J. 1987. Macroinvertebrate populations in seasonally flooded marshes in the northern San Joaquin Valley of California. Thesis, Humboldt State University, Arcata, California, USA.

when competing with mallards for the larger watergrass seeds. Thus, with mallards more abundant in the GEA than in the Tulare Basin and Mendota WA (California Department of Fish and Game, Sacramento, California, unpublished data), pintails in the GEA may have selected timothy rather than watergrass marsh for feeding because they have the competitive advantage over mallards when feeding on timothy seeds but not on the larger watergrass seeds. Pintails do feed extensively on the relatively large rice seeds in the Sacramento Valley (Miller 1987), where mallards are even more abundant than in the GEA (California Department of Fish and Game, Sacramento, California, unpublished data). However, other factors such as seed abundance or the lack of emergent vegetation may make harvested rice fields attractive to pintails even when mallards are abundant.

Our finding that foraging pintails selected swamp timothy is consistent with food habit studies at Los Banos WA (Beam and Gruenhagen[4] 1980, Connelly and Chesemore 1980) where seeds of swamp timothy were the most common vegetative food found in collected birds. However, watergrass seeds were also very common in pintails collected on Los Banos WA, suggesting that either habitat use on Los Banos WA was not representative of habitats used throughout the GEA, or use of watergrass during our study was lower than during those studies. Beam and Gruenhagen[4] (1980) did conclude that swamp timothy was the most sought after food by pintails because although swamp timothy decreased in importance during winter as watergrass (and associated sprangletop, *Leptochloa* spp.) increased, pintails did not use watergrass in greater proportion than its availability. Miller (1983) observed pintails diving for swamp timothy seeds in the Sacramento Valley.

Pintails selected open and shallow seasonal marsh and flooded fields during most days and all nights and avoided deep habitats (i.e., evaporation and sewer ponds, reservoirs). Isola et al. (2000) also reported that water depth, percent open water, and percent emergent vegetation were the most highly correlated factors with pintail diurnal foraging sites in GEA marshes; they did not measure night use. Euliss[3] (1984) reported highest pintail day use in open marsh at Kern NWR but that densely vegetated marsh (especially watergrass) received nearly all night use by pintails. It is unclear why our night use findings disagreed with Euliss[3] (1984), but open habitats, especially timothy marsh and rice fields, were selected by pintails we located at night and in contrast to the conclusion made by Euliss[3] (1984) that pintails avoid open habitats at night.

Roosting Habitat Selection

Numerous factors determine where pintails roost. During this study, most pintails in GEA roosted near foraging sites (Fleskes et al. 2002a), but before San Luis NWR and other sanctuaries were established in the 1960s, most flew to San Luis Reservoir on shoot days (California Department of Fish and Game, Sacramento, California, USA, unpublished data), a situation similar to that described by Cox and Afton (1997). Thus, disturbance avoidance was probably more important in roost selection than other site

characteristics (Wolder[16] 1993). During nonhunting intervals and nonshoot days, most pintails day-roosted in the same areas used at night, indicating that if undisturbed, pintails prefer to roost near foraging sites in shallow, open habitats. High shoot day ranking of watergrass may have been coincidental because most watergrass in the GEA was in San Luis and Merced NWR sanctuaries.

Pintail Age and Condition

Habitat selection by HY and AHY female pintails was similar, although ranking significance differed. Immature birds have been reported to be less selective (Draulans and Vessem 1985, Warnock and Takekawa 1995), but the less significant rankings that we observed in some instances for HY could also be due to their smaller sample sizes. We observed no relationship between pintail body condition in fall and habitat use during winter.

MANAGEMENT IMPLICATIONS

Preferred late-winter habitats were apparently lacking in the GEA during 1991-94, at least relative to in the Sacramento Valley and Delta, where most pintails moved to in December each year. Abundance of pintails in the GEA declined greatly during December as most went to the Sacramento Valley or Delta (Fleskes et al. 2002b). Some radio-tagged pintails revisited the GEA but only briefly before again going back to the Sacramento Valley or Delta (Fleskes et al. 2002b).

Although numerous factors, including the amount of sanctuary, impacts how attractive landscapes are to pintails, the earlier decline of seeds in the pintail diet in the GEA than in the Sacramento Valley (Beam and Gruenhagen[4] 1980, Connelly and Chesemore 1980, Miller 1987) and the long flights that pintails made to rice fields in the GEA immediately upon their flooding (Fleskes 2002a), indicates that food supplies, especially seeds, were probably depleted or at least less abundant in the GEA than in the Sacramento Valley and Delta by late-winter. Most SJV wetlands are intensively managed to maximize seed production and are flooded fully by early November to allow waterfowl hunting or provide sanctuary. This system apparently provides good early-winter habitat most years but has only partially mitigated the loss of late-winter habitat. Future management should increase preferred late-winter habitats and amounts of foods available to pintails during late-winter. Incentives could be used to encourage flooding of harvested rice or other preferred crops during late winter and delay flooding of some new or existing wetlands.

Restoration efforts for pintails should emphasize shallow habitats (i.e., $\leq$30 cm, Isola et al. 2000). Pintails that we studied clearly preferred shallow over deep-water habitats and given adequate quantities of high quality shallow-water habitats, pintails would

[16]Wolder, M. A. 1993. Disturbance of wintering northern pintails at Sacramento National Wildlife Refuge, California. Thesis, Humboldt State University, Arcata, California, USA.

be diverted away from evaporation and sewer ponds, thus reducing the contaminant and disease risk sometimes associated with those areas (Moulton et al. 1976, Custer et al. 1996, Lemly and Ohlendorf 2002). Female pintails selected timothy marsh whenever available and management plans emphasizing this habitat would benefit pintails. Information on seasonal availability and depletion rates of seeds and invertebrates are needed for habitats throughout the Central Valley.

In contrast to concern of the past trend towards open marshes (Euliss and Harris 1987), we caution that monitoring is needed to determine what impact a shift in the SJV towards more closed marsh will have on pintails, shorebirds, and other fauna that are associated with open wetland habitats. An increased discrepancy in the daily bag limit for mallards and pintails (0 difference before 1988, 2-3 more mallards permitted during 1988-94, 4-6 more mallards during 1995-99, California Department of Fish and Game, Sacramento, CA, USA, unpublished data) may lead to increased conversion of open marsh to hemi-closed permanent or semi-permanent marsh, that managers perceive as being more favorable for mallard harvest or production. Increased water availability due to the 1992 Central Valley Project Improvement Act (Davis 1992) has provided managers with the opportunity to provide a more diverse array of habitats and may increase conversion of timothy wetlands to watergrass wetlands, that require more water but can produce greater seed crops. As seen in Kern NWR (Euliss and Harris 1987) and Mendota WA (Fleskes[2] 1999), watergrass marsh can be attractive to pintails and has potential to provide late winter seeds that pintails are apparently seeking when they move to Sacramento Valley rice fields. However, additional research is needed to determine why pintails selected watergrass for feeding in some SJV areas but not in GEA during this study.

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POTENTIAL FOR RESTORATION OF A CALIFORNIA STREAM NATIVE FISH ASSEMBLAGE

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The South Yuba River has a depleted native fish fauna, with five of the expected nine native fish species absent because of past human impacts on the system. Anadromous Pacific lamprey, *Lampetra tridentata*, and chinook salmon, *Oncorhynchus tshawytscha*, are excluded by a downstream barrier. Three smaller native species, riffle sculpin, *Cottus gulosus*; California roach, *Lavinia symmetricus*; and speckled dace, *Rhinichthys osculus*, were probably extirpated from the South Yuba River by the effects of hydraulic mining in the late 1800's. The fish community of the South Yuba River can be partially restored through reintroductions.

INTRODUCTION

There has been a severe decline of the native fish fauna of California, largely due to water diversions, watershed degradation, and introduction of exotic species (Moyle and Williams 1990). This trend is exemplified by the South Yuba River, which has been subject to many types of human impacts, including: 1) elevated current and historical sediment loadings as a result of hydraulic mining at Malakoff Diggins in the late 1800s, 2) elevated water temperatures due to flow regulation, 3) predation and competition by introduced fish species, and 4) blockage of anadromous fish passage due to downstream dam construction. The expected native fish assemblage in a Sierra foothill stream, such as the South Yuba River, would be rainbow trout, *Oncorhynchus mykiss*; Sacramento pikeminnow, *Ptychocheilus grandis*; hardhead, *Mylopharodon conocephalus*; Sacramento sucker, *Catostomus occidentalis*; California roach, *Lavinia symmetricus*; speckled dace, *Rhinichthys osculus*; Pacific lamprey, *Lampetra tridentata*; chinook salmon, *Oncorhynchus tshawytscha*; and riffle sculpin, *Cottus gulosus* (Moyle 2002). Anadromous Pacific lamprey and chinook salmon were present in the 1920s and 1930s[2], but are now excluded by Englebright Dam, located downstream of the South Yuba River and constructed in 1939-40.

The California State Department of Parks and Recreation's (State Parks) management objectives for the South Yuba River are to maintain/restore the native fish community, and to improve the habitat for these species (T.L. Taylor, State Parks, personal

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[2] Gard, M.F. 1994. Biotic and abiotic factors affecting native stream fishes in the South Yuba River, Nevada County, California. Ph.D. thesis. University of California, Davis.

communication). However, evaluating the feasibility of restoring the native fish community requires knowledge of the causes of extinction, factors limiting the existing fish populations, and the suitability of the habitat for reintroductions.

The objectives of this study were to determine: 1) the fish species composition in the South Yuba River; and 2) the distribution and abundance of each species. In addition, I evaluate the potential for reintroduction of native fish species to aid in the conservation of native fishes in the South Yuba River watershed as part of a statewide system of aquatic habitats managed for biodiversity (Moyle and Yoshiyama 1994).

STUDY AREA

Much of the South Yuba River watershed above Humbug Creek (Figure 1) lies within the Tahoe National Forest, administered by the U.S. Forest Service. State Parks manages two areas within the South Yuba River watershed: Malakoff Diggins State Historic Park, in the Humbug Creek drainage, and the South Yuba River State Park, adjacent to the South Yuba River (R. Patton, State Parks, personal communication). Additional lands along the South Yuba River are included in the South Yuba Recreation Area, managed by the U.S. Bureau of Land Management (BLM).

The South Yuba River is located on the western slope of the Sierra Nevada, in the Sacramento River basin. The South Yuba River is 102 km long, with a mean gradient of 10.4%, and drains approximately 900 km^2 (Palmer and Vileisis 1993). The study area, located near Nevada City, comprised the lowermost 38 km of the South Yuba River (165-701 m above sea level), from Missouri Bar to Bridgeport (Figure 1), where the South Yuba River enters Englebright Reservoir. Mean daily maximum water temperatures at Jones Bar for 1967-1979 ranged from 5°C in December and January to 24°C in July[3]. Flows in the South Yuba River are highly regulated as a result of 20 upstream reservoirs. Channel slopes of the South Yuba River within the study area vary from 0.3% to 7.9%[3].

METHODS

Field studies were conducted on the South Yuba River during the summers of 1991, 1992, and 1993. Fish were sampled in the South Yuba River at nine sites: Bridgeport, Jones Bar, Highway 49, Hoyt Crossing, Purdon Crossing, Edwards Crossing, Illinois Crossing, Humbug Creek and Missouri Bar (Figure 1). Sampling of the sites was stratified by habitat types (pool, run, riffle, or glide). Habitat types were delineated using Morhardt's habitat-typing system[4]. Pools were defined as having a maximum depth greater than 1 m and an average velocity of less than 0.3 m/s. Glides were defined as having a maximum depth less than 1 m and an average velocity of less than 0.3

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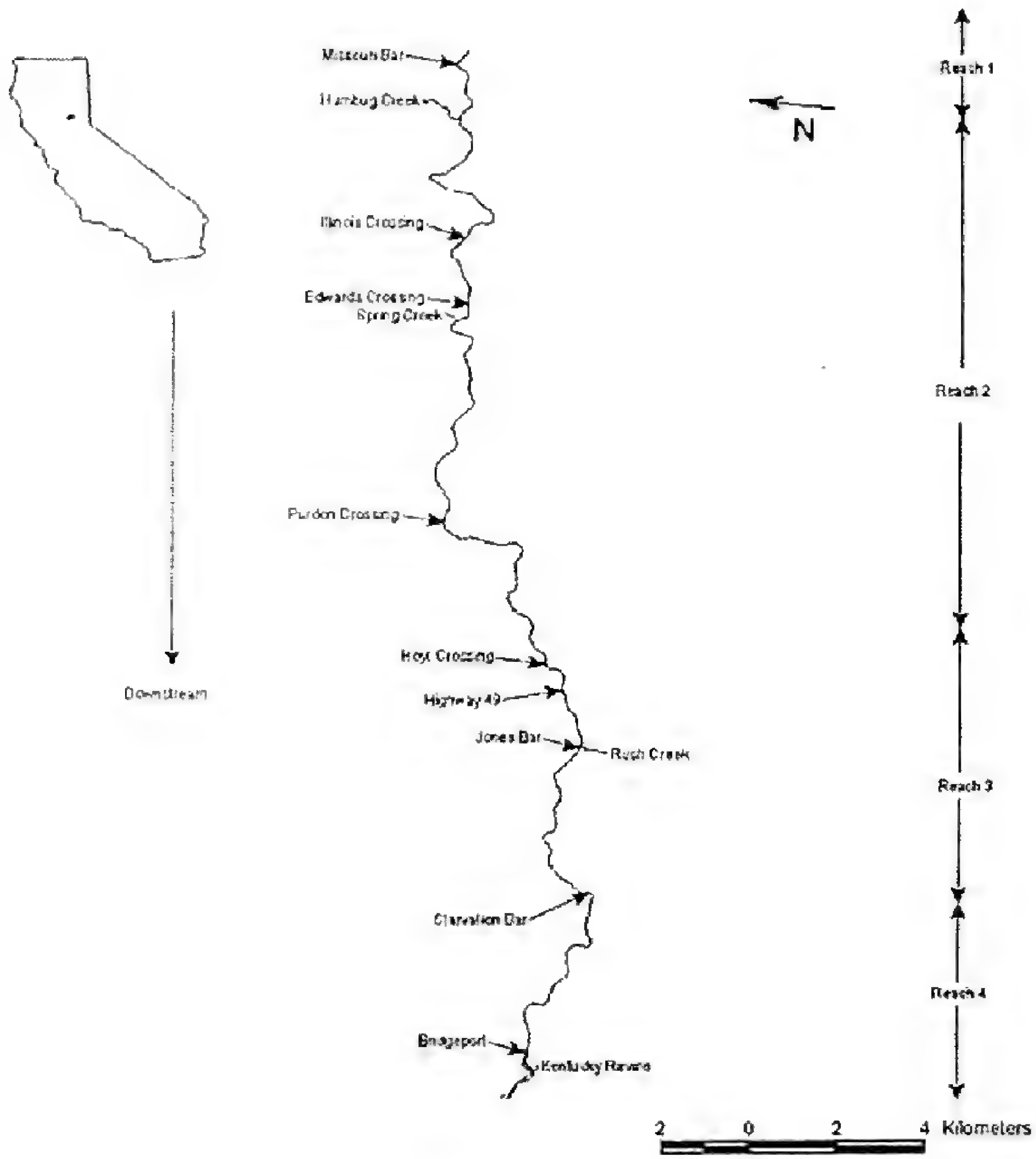

Figure 1. Map of South Yuba River sampling sites.

m/s. Runs were defined as having a maximum depth greater than 1 m and an average velocity greater than 0.3 m/s. Riffles were defined as having a maximum depth less than 1 m and an average velocity of greater than 0.3 m/s.

The fish species composition of riffles and glides were determined by single-pass electrofishing. The abundance and composition of fish species in pools and runs was estimated using snorkel surveys, where two or three people swam upstream and counted the number of fish (enumerated by species and size class). The size classes used were <50 mm, 50-150 mm, 150-250 mm, and >250 mm for pikeminnow, hardhead,

and smallmouth bass, *Micropterus dolomieui*; < 50 mm, 50-250 mm, and > 250 mm for suckers; < 100 mm and > 100 mm for green sunfish, *Lepomis cyanellus*, and bluegill, *Lepomis macrochirus*; < 100 mm, 100-200 mm, and > 200 mm for rainbow trout; and < 250 mm and > 250 mm for brown bullhead, *Ictalurus nebulosus* and common carp, *Cyprinus carpio*. Snorkel surveys were also performed between Jones Bar and Bridgeport in 1992, between Starvation Bar (5 km above Bridgeport) and Bridgeport in 1993, and above Hoyt Crossing in 1992. Only the snorkel surveys were used to assess abundance, while both the snorkel survey and electrofishing data were used to determine distribution. Snorkeling counts and electrofishing data were not pooled to determine relative abundance, since the two methods do not provide comparable estimates of fish abundance.

RESULTS

The following native fish species were found in the South Yuba River: rainbow trout, Sacramento pikeminnow, Sacramento sucker, and hardhead. In addition, the following introduced fish species were observed: smallmouth bass, green sunfish, bluegill, brown bullhead, and common carp.

Rainbow trout were most abundant in the South Yuba River in Reach 1 (Table 1), and were much more abundant at all locations in the South Yuba River in 1993 than in 1991 and 1992. For example, I observed 16 rainbow trout below Starvation Bar in 1993, and observed no rainbow trout below Jones Bar in 1992. The few rainbow trout found in the South Yuba River in Reaches 2, 3, and 4 in the summers of 1991 and 1992 were adults, and were generally near colder-water tributaries or below a waterfall (where dissolved oxygen concentrations would be high).

Sacramento sucker adults were found throughout the South Yuba River (Table 1), but in fairly low numbers (an average of one to two large individuals [around 350 mm SL] per snorkeled section). Juvenile suckers [100 to 250 mm SL] were typically the only fish found in riffle and shallow run habitats in Reaches 1, 2 and 3, while age-0 suckers were usually found in shallow areas of pools in the South Yuba River.

Sacramento pikeminnow were found in the South Yuba River throughout the study area, and were by far the most abundant fish species in the South Yuba River in Reaches 1 and 2 (Table 1). Hardhead were found in the South Yuba River in Reaches 3 and 4 (Table 1). Smallmouth bass were only found in the South Yuba River in Reach 4, along with most individuals of other introduced fish species (Table 1). Smallmouth bass were the most abundant fish species in pools in Reach 4, and young-of-year smallmouth bass were the only fish found in riffles at Bridgeport. The upstream limit of smallmouth bass appears to be controlled by a large cascade at the upper end of Reach 4, which is apparently an upstream barrier for this species. In both 1992 and 1993, smallmouth bass were only found downstream of this cascade. Occasional individuals of other introduced fish species were observed farther upstream (Table 1).

Table 1. Abundance and distribution of fish species in the South Yuba River. Definition of abundance categories: A = abundant (> 30 percent of fish present), F = few (< 10 percent of fish present), R = rare (< 1 percent of fish observed), N = not present. Abundance of rainbow trout and sunfish in the South Yuba River varied with year. See Figure 1 for locations of reaches for the South Yuba River. YOY fish are rainbow trout less than 100 mm. Juvenile fish are < 250 mm for pikeminnow, sucker, hardhead, and smallmouth bass, and are 100-200 mm for rainbow trout. Adult fish are > 250 mm for pikeminnow, sucker, hardhead, and smallmouth bass, and are > 200 mm for rainbow trout. Abundance was evaluated based on snorkel survey data, while distribution was based on both snorkel survey and electrofishing data.

a. Native Fish Species

	Rainbow trout			Sacramento pikeminnow		Sacramento sucker		Hardhead	
Reach	YOY	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Reach 1	F	F	F	A	A	F	F	N	N
Reach 2	R	F/R	F/R	A	A	F	F	N	N
Reach 3	N	F/R	F/R	A	A	F	F	A	A
Reach 4	N	N	F/N	R	F	R	F	R	F

b. Introduced Fish Species

			Smallmouth Bass			
Reach	Green sunfish	Bluegill	Juvenile	Adult	Brown bullhead	Carp
Reach 1	N	N	N	N	N	N
Reach 2	N	N	N	N	N	N
Reach 3	R	N	N	N	R	N
Reach 4	A/F	A/F	A	A	R	R

DISCUSSION

A statewide system of aquatic habitats managed for biodiversity (Aquatic Diversity Management Areas [ADMA]) has been proposed as a means of stemming the decline of native California fish species (Moyle and Yoshiyama 1994). The South Yuba River is a good candidate for an ADMA, because most of the land along the South Yuba River is already managed by public agencies, whose mandates and missions include the conservation of native species. Factors to consider in selecting an ADMA include: 1) protection of entire drainages; 2) barriers that prevent invasion of introduced species from downstream areas; and 3) wide buffer zones to protect aquatic ecosystems from disturbances in adjacent terrestrial environments (Moyle and Yoshiyama 1994). Schlosser (1991) also stressed the importance of considering the entire drainage, through the use of landscape ecology principles, in conserving stream fishes. The

South Yuba River would be classified as a Class III ADMA (an area which has been extensively and largely irreversibly modified by human activities despite its natural appearance) under Moyle and Yoshiyama's (1994) classification system, since sediment loads and flow regulation have extensively and largely irreversibly modified the South Yuba River, despite its natural appearance. Moyle and Sato (1991) suggest that management of Class III preserves focus on species or habitat types, rather than ecosystems. In applying these principles to the South Yuba River, including considering the reintroduction of missing species, factors which will impede the conservation of the native fish species, as well as the feasibility of overcoming these impediments, must first be considered.

Speckled dace, California roach, and riffle sculpin were apparently extirpated from the South Yuba River by the tremendous sediment loads from hydraulic mining in the late 1800's (Gard 2002). Based on the distribution of these species in other Central Valley watersheds (Moyle 2002), it is likely that these species would have present in the South Yuba River prior to hydraulic mining. Current sediment loads from Malakoff Diggins appear to have relatively little effect on the South Yuba River biotic community. Pikeminnow growth rates appear to be adversely affected by sediment loads, based on an analysis of condition index data; however, there appears to be no adverse effect of current sediment loads on aquatic macroinvertebrates, and fish survival and reproduction (Gard 2002).

Monitoring of the distribution and abundance of fish species via snorkel surveys and electrofishing is important in evaluating the effectiveness of other management actions and developing alternative management actions. At a minimum, annual snorkel surveys from Starvation Bar to Bridgeport would show whether or not the upper end of the distribution of smallmouth bass had extended upstream, potentially requiring additional controls, such as electric fish barriers or smallmouth bass eradication efforts.

With the probable exception of excessive temperature for chinook salmon, existing habitat in the South Yuba River would be capable of satisfying the ecological requirements of the missing native fish species. However, reintroduction of chinook salmon and Pacific lamprey to the South Yuba River would require the installation of fish passage facilities at Englebright Dam to eliminate the current barriers to migration. A smaller debris dam, Daguerra Dam, located 6.8 km downstream of Englebright Dam, has fish ladders which allow substantial upstream passage of chinook salmon, but could be an upstream migration barrier for lamprey. In addition, passage of upstream and downstream migrants through Englebright Reservoir could also be a problem.

In contrast, the reintroduction of speckled dace, California roach, and riffle sculpin to the South Yuba River would not require any such structures. These species should only be reintroduced upstream of Starvation Bar, since predation by smallmouth bass would likely make the reintroduction of these small-bodied species downstream of Starvation Bar unsuccessful. Reintroduction of riffle sculpin immediately below active suction dredging areas could also be a problem, given the deleterious local effects of suction dredging on this species (Harvey 1986). Suction dredging is ongoing at several locations in the study area. Since these species have been sympatric with Sacramento pikeminnow for a relatively long period of time, they should be able to withstand

pikeminnow predation. For example, roach in the Eel River basin were able to maintain their populations after the invasion of pikeminnow (Brown and Moyle 1991, Brown and Moyle 1997). In addition, since they have been sympatric with all of the native species currently present in the South Yuba River for a long period of time, they would not be likely to have an adverse effect on the current species as a result of competition; this is supported by the greater fish numbers and biomass in the South Yuba River in Reach 3, where hardhead are present, compared to the native fish assemblage at and above Purdon Crossing (Gard 2002). In fact, the reintroduction of these species might have a beneficial effect on pikeminnow by providing an additional food supply for large pikeminnow. Stocking programs could also extend the distribution of hardhead further upstream.

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ACANTHOCEPHALA CYSTACANTH INFECTIONS IN SAND CRABS FROM BODEGA BAY, CALIFORNIA

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Three species of *Profilicollis: major, kenti,* and *altmani* (Phylum Acanthocephala, Family Polymorphidae) have been implicated in the cause of morbidity and mortality of the southern sea otter, *Enhydra lutris nereis*, population along the coast of California from Santa Cruz to Morro Bay. The usual definitive hosts in the life cycle of *Profilicollis* spp. are shore birds, and it has been suggested that the sand crab, *Emerita analoga* , is the intermediate host. Studies of the food habits of sea otters in California suggest that they acquire the infection by eating infected sand crabs. The purpose of this project was to determine if sand crabs from the Bodega Bay area might harbor these parasites and contribute to sea otter infections. The results of this study showed that there are at least three different species of acanthocephalans infecting sand crabs from Bodega Bay. Two of the species represent those found in sea otters from California, suggesting that the otters may be migrating to the Bodega Bay region and acquiring the infection there.

INTRODUCTION

According to surveys performed by the 1999 U.S. Geological Survey, Biological Resources Division, the population of sea otters, *Enhydra lutris nereis*, along the California coast from Santa Cruz to Morro Bay has declined over the last decade. A

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recent study of sea otter mortality conducted by the National Wildlife Health Center examined 195 sea otter carcasses over a 3-year period (Thomas and Cole 1996). A high percentage of deaths were attributed to infectious diseases (Thomas and Cole 1996); many of these deaths were due to peritonitis caused by acanthocephalan parasites belonging to the genus *Profilicollis* (= *Polymorphus*, Nickol et al. 1999).

Sea otters from central California have been reported to be infected with two genera of Acanthocephala: *Profilicollis* and *Corynosoma* (Hennessy and Morejohn 1977). The sea otter is the only reported host of *Corynosoma enhydri* and to date has not been implicated in the penetration of the intestinal wall (Margolis et al. 1997). *Profilicollis* spp. on the other hand, normally infect marine birds such as gulls and scoters (Reish 1950). In sea otters however, immature *Profilicollis* spp. penetrate the intestinal wall, resulting in necrotic ulceration, secondary bacterial infections, and peritonitis. Thomas and Cole (1996) suggested that these infections may contribute to sea otter mortality along the coast of California.

Recent studies by Thomas and Cole (1996) showed that the sand crab, *Emerita analoga*, from Monterey Bay is infected with the cystacanths of two species of *Profilicollis* (*P. kenti* and *P. altmani*) and are a food source of the otter. Hence, sand crabs represent a potential intermediate host of *Profilicollis* spp.

The purpose of this project was to determine if the sand crab from Bodega Bay might harbor *Profilicollis* spp., which can potentially infect sea otters.

METHODS

Sand crabs were collected from the intertidal (swash) zone along Salmon Creek in Bodega Bay during July 1999. A total of 14 crabs measuring in size from 2.5 - 5.0 cm was dissected using a dissecting scope to remove cystacanths from the hemocoel. Cystacanths were counted and placed in room temperature deionized water to encourage extension of the proboscis. Once excised, the cystacanths were cleaned and stored in 70% ethanol. Specimens were stained using Carmine stain, destained in acid alcohol, dehydrated to 100% ethanol, cleared in xylene, and mounted with Permount[3]. Additional worms were dehydrated as above, dried in hexamethyldisilazane, gold coated, and examined by scanning electron microscopy.

Parasites were identified according to Amin (1992) using number of proboscis hook rows and number of hooks/row. Cystacanths consisted of two identified species (*Profilicollis major* Lundstrom, 1942, 18-22 rows with 10-15 hooks/row; *P. altmani* Perry, 1942, 30-32 rows with 11-13 hooks/row) and one unidentified *Profilicollis* morphotype containing 23-28 rows with 12-17 hooks/row (Table 1).

To determine if larger crabs had more parasites, a simple linear regression analysis was performed comparing the total length of the crab and the intensity of infection (number of cystacanths per crab). Alpha was set at 0.05.

[3]Use of trade names does not imply endorsement by the California Department of Fish and Game

Table 1. Key characteristics in grouping cystacanths found in sand crabs.

Group (# of cystacanths)	Row count	# of Hooks/row	Species
Group 1 (n = 14)	18-22	10-15	*Profilicollis major*
Group 2 (n = 5)	30	11-13	*Profilicollis altmani*
Group 3 (n = 24)	24-28	12-17	Undetermined

RESULTS

A total of 43 cystacanths was collected from 14 Bodega Bay sand crabs. Of the two identified species, a higher number of *P. major* (14/43, in 10/14 [71%] of the crabs) was found compared to *P. altmani* (5/43, in 2/14 [14%] of the crabs). The unidentified morphotype was the most numerous (24/43) cystacanth type recovered (Fig. 1) but was found in fewer crabs compared to *P. major* (8/14 [57%]).

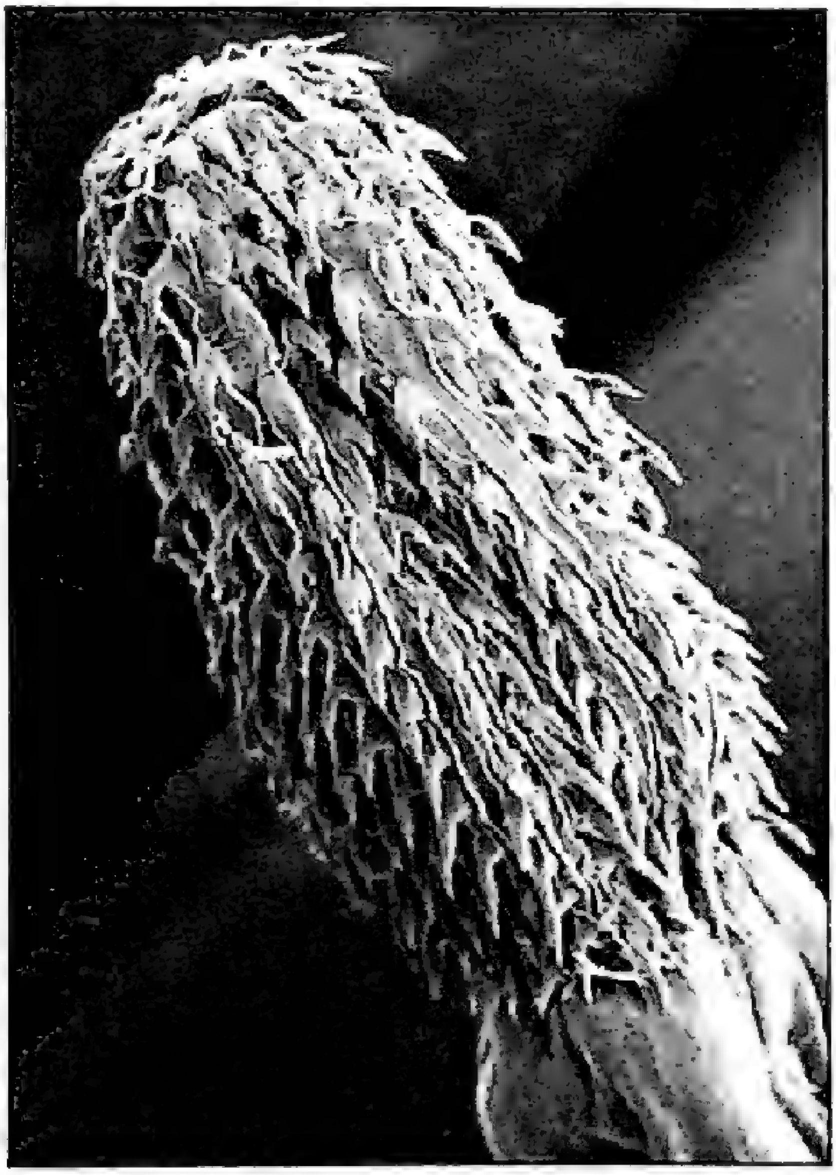

Figure 1. Scanning electron micrograph of the anterior end of one of the cystacanths assigned as an undetermined species.

Nine of the 14 crabs had single species infections: 6 with 1-3 *P. major* cystacanths per crab and 3 with 1-6 unidentified species of cystacanths per crab. Single infections were found in 4 of the 6 *P. major* and one of the unidentified species. No single infections of *P. altmani* was found.

Multiple *Profilicollis* spp. infections were observed in 5 of the 14 sand crabs (Fig. 2). Of the 5 cases of multiple parasite infections, 3 crabs were infected with *P. major* and the unidentified species in 1:1, 1:3, and 1:4 ratios; in the fourth crab, *P. altmani* and the unidentified species were found in a ratio of 1:3; in the fifth crab, the three species occurred in a 5:2:4 ratio, respectively.

The intensity (average number of parasites per host) of infection was 3.7 cystacanths per crab (range = 1-9). The size of crab (as measured by total length) was not significantly related to the intensity of infection ($r^2 = 0.291$; $p > 0.05$; $n = 14$ crabs).

Specimens of *P. major* and *P. altmani* have been deposited in the United States National Parasite Collection, United States Department of Agriculture, Beltsville, Maryland and given the accession numbers USNPC# 091998.00 and 091999.00, respectively.

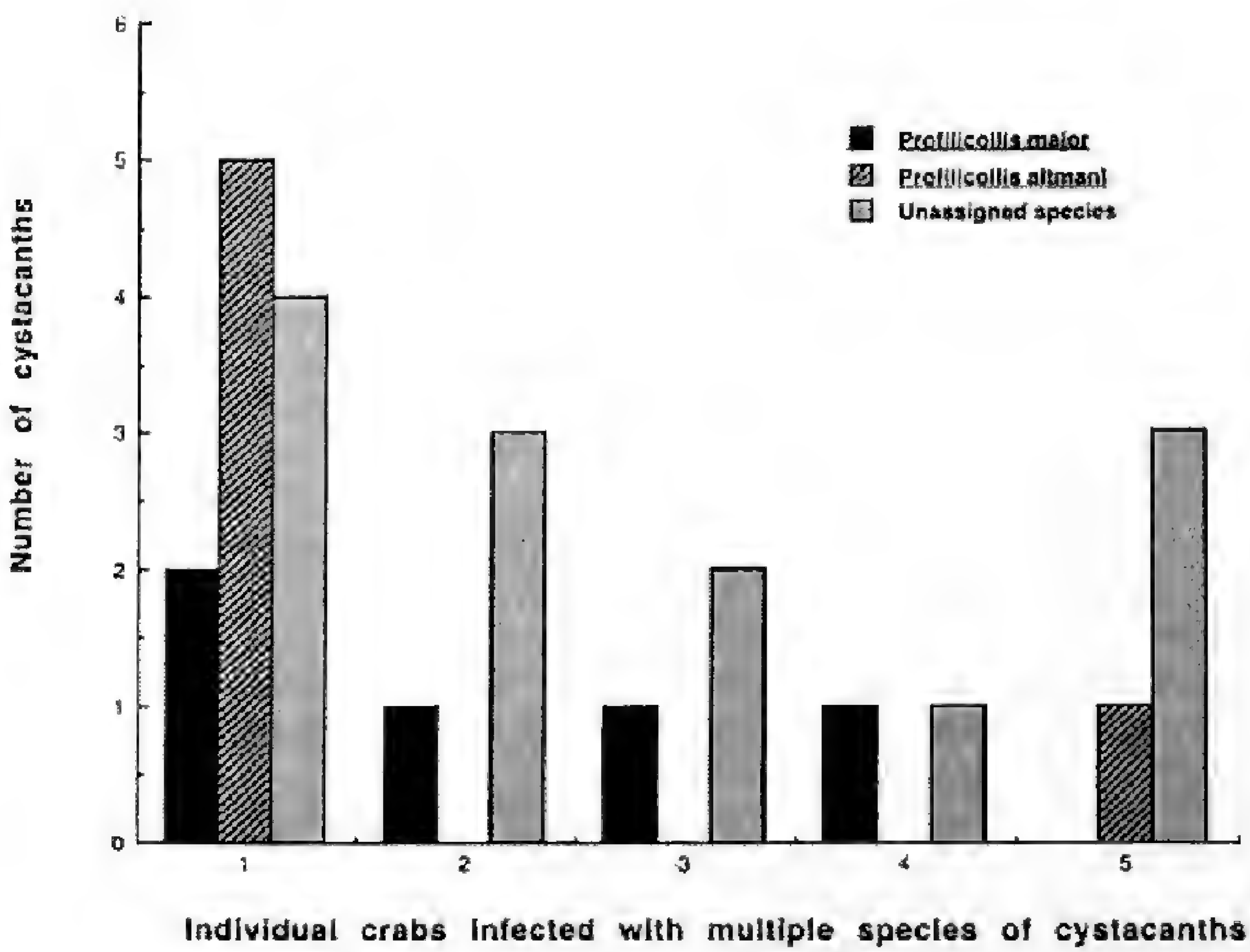

Figure 2. Number of cystacanth infections in five individual sand crabs collected in July 1999 from Bodega Bay, California.

DISCUSSION

Several studies have been undertaken to compare the California and Alaska sea otter populations to understand the factors which may contribute to the declining California sea otter populations. In a study of more than 1,000 Alaskan sea otters, Margolis et al. (1997) found that unlike California sea otters, which were infected by both *Profilicollis* spp. and *C. enhydri*, the Alaskan otter population was infected by three species of acanthocephala in the genus *Corynosoma (C. enhydri, C. stromosum,* and *C. villosum).* They also found that the Alaskan sea otter population was relatively free of the disease in contrast to California sea otters, which react pathologically to infection by various *Profilicollis* spp.

The difference in pathology observed between these two populations may be the result of host specificity and the mode of transmission of the different acanthocephalan species. The Alaskan sea otters are infected with several types of parasites transmitted mostly by fish and shorebirds. California sea otters, on the other hand, are not infected by parasites that are typically transmitted by fish, and forage primarily on invertebrates including sand crabs, an intermediate host of *Profilicollis*.

In this study, we found that sand crabs from Bodega Bay were infected with cystacanths of *P. major* and *P. altmani*, as well as an undetermined species of acanthocephalan. Mayer et al. (2003) found that California sea otters from the Monterey Bay area were infected with three species of *Profilicollis*: *P. major*, *P. kenti*, and *P. altmani*. Cystacanths of *P. major* however, were not found in the sand crabs collected from the Monterey Bay area (K. Mayer, Monterey Bay Aquarium, personal communication) which may suggest that California sea otters might acquire *P. major* infections from another site in northern California.

Fourteen sand crabs from Bodega Bay had an intensity of infection of 4, with one crab having 9 cystacanths contained within its hemocoel. No *P. kenti* were recovered from any of the crabs. Multiple infections of *P. major*, *P. altmani*, and the undetermined species occurred in 5 of the 14 sand crabs sampled, a finding that has not yet been reported. Multiple infections of *Profilicollis* spp. in California sea otters is not surprising because they may be foraging on sand crabs harboring multiple infections.

In summary, this study showed that sand crabs from Bodega Bay, California are infected with cystacanths of *Profilicollis major*, *P. altmani*, and an unidentified species. These infections may be contributing to the infections acquired by sea otters in California as the sea otters migrate along the coastal waters between Monterey and the northern waters of San Francisco Bay area.

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SEXUAL DIMORPHISM IN WING MEASUREMENTS OF COMMON SNIPE

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INTRODUCTION

Arnold (1994) proposed that an economical technique for accurately distinguishing common snipe, *Gallinago gallinago,* sexes is needed for monitoring this declining neotropical migrant (DeGraaf and Rappole 1995). Because common snipe are migratory game birds, Fogarty et al. (1977) suggested that wings obtained from hunters might permit large-scale population monitoring (Hoffman 1981). Consequently, a sexing technique using wing characteristics is desirable.

Distinguishing sexes by morphometric differences would seem reasonable because previous research documented that, although generally monomorphic, common snipe females are typically larger than males (White 1963[2], Whitehead 1962[3], Tuck 1972, Hofmann 1987[4]). Because wing morphometrics of common snipe have received only limited study (Arnold 1994), I explored the potential for differentiating sexes of specimens collected in northwestern California.

METHODS

Common snipe were collected from hunters at the Elk River Wildlife Area in northwestern California between 7 October 1989 and 21 January 1990 (Edelmann 1991). Individuals were sexed internally, aged (Dwyer and Dobell 1979), and the less damaged wing was retained. Wings were opened fully, pinned to a board, and air-dried for $\geq$60 days before measuring wing characteristics with a civil engineer's ruler (French et al. 1974).

I measured wing characteristics reported to differ between sexes of common snipe and confamilials (Greeley 1953, White 1963[2], Whitehead 1962[3], Tuck 1972. Artman and Schroeder 1976): 1) 1st-secondary width 1.0 cm below tip, 2) 1st-secondary rachis

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[2]White, M. 1963. Occurrence, habitat ecology, food habits, and sex and age studies of the Wilson snipe in the Humboldt Bay region. M.S. Thesis, Humboldt State University, Arcata, California. 90 pp.

[3]Whitehead, C. J., Jr. 1962. Foods and feeding habits of the common snipe (*Capella gallinago delicata*) in Cameron Parish, Louisiana, with ecological notes and discussion of methods of sexing and aging. M.S. Thesis, Louisiana State University, Baton Rouge. 85 pp.

[4]Hofmann, P. S. 1987. Ecological and biological aspects of the common snipe in California. M.S. Thesis, Humboldt State University, Arcata, California. 88 pp.

length, 3) 10th-primary width 2.0 cm below tip, 4) 10th-primary rachis length, and 5) wing chord. I plucked and consistently flattened each feather before measuring lengths and widths. I measured wing chord from the carpals to the tip of the 10th-primary rachis. According to Whitehead (1962)[3], I estimated measurements to the nearest 0.1 mm but rounded to the nearest whole millimeter for analyses. Half-millimeter measurements were rounded upward to the next whole millimeter.

I used multivariate analysis-of-variance (Manova) to determine if wing characteristics were significantly 1) different between sexes, 2) affected by age, and 3) influenced by an interaction between sex and age. I then used canonical discriminant analysis (CDA) with combinations of significant characteristics to calculate Mahalanobis distance (D^2) functions and cut-point values between group centroids for statistically separating sexes (Hair et al. 1987; SAS Institute, Inc. 1989). Performance of CDA functions was evaluated with correct-classification rates estimated with resubstitution (Lachenbruch and Mickey 1968). Tests were considered significant at $P \leq 0.05$.

I also applied the sexing technique with which Whitehead (1962)[3] correctly classified 95% of common snipe collected in Louisiana. This technique classifies individuals with 1st-secondary widths $\leq$14 mm as males and $\geq$15 mm as females.

RESULTS

Wings from 179 common snipe (58 juvenile and 30 adult males, and 68 juvenile, and 23 adult females) were collected and analyzed. No significant age effect ($P = 0.33$) or sex by age interaction ($P = 0.66$) was detected with Manova. However, sexes differed ($P < 0.01$) primarily because of univariate differences in 1st-secondary width and 1st-secondary length ($P < 0.01$) (Table 1). Although females averaged larger than males, all differences were small (<2 mm) (Table 1).

To assess if significant wing characteristics could accurately predict sex, I performed two CDAs by iteratively adding each significant characteristic to improve correct classification rates (Table 2). The first CDA function contained only 1st-secondary width, which accurately predicted sex for common snipe in Louisiana (Whitehead 1962)[3]. I added 1st-secondary length in the second function.

Neither CDA function reliably distinguished sex. For both functions, D^2s between centroids were small (Table 2) with much group overlap between sexes. Accordingly, correct-classification rates were low for both sexes in each CDA function; the 1- and 2-variable CDAs correctly classified 59% and 65% of individuals, respectively (Table 3).

Whitehead's (1962)[3] technique correctly classified 58% of my samples with skewed rates between sexes (83% for males versus 33% for females) (Table 3). This correct-classification rate was far below the 95% reported for Louisiana (Whitehead 1962)[3]. Mean 1st-secondary widths were smaller for females from northwestern California (14.1 mm) than Louisiana (15.3 mm), and slightly larger for males from northwestern California (13.6 mm) than Louisiana (13.3 mm) (Whitehead 1962)[3].

Table 1. Morphological measurements for common snipe sexes collected in northwest California, 1989-1990.

	Male ($n = 88$)				Female ($n = 91$)				
Characteristic	Mean (mm)	Standard deviation	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard deviation	Minimum (mm)	Maximum (mm)	$P > F$
1st-secondary width	13.6	0.9	11	15	14.1	0.9	12	16	0.01
1st-secondary length	68.0	2.2	57	77	69.6	2.2	64	79	0.01
10th-primary width	10.5	0.8	9	13	10.6	0.8	8	12	0.87
10th-primary length	102.1	2.8	94	107	102.5	3.0	94	109	0.54
Wing chord	132.9	3.6	125	141	133.3	3.9	121	145	0.45

Table 2. Results of canonical discriminant analyses (CDA) using morphological measurements for distinguishing common snipe sexes collected in northwestern California, 1989-1990.

CDA Function	Canonical coefficients: 1st-secondary Width	Canonical coefficients: 1st-secondary Length	Centroids: Male	Centroids: Female	Group cut-point	D^2
1-variable	1.0794		14.7066	15.2063	14.9067	0.2497
2-variable	0.5974	0.3661	33.0477	33.8911	33.4764	0.7113

Table 3. Classification results of canonical discriminant analyses (CDA) using morphological measurements for distinguishing common snipe sexes collected in northwestern California, 1989-1990.

Group	Sample size	Correct classification: 1-variable CDA Function	Correct classification: 2-variable CDA Function	Correct classification: Whitehead's technique
Male	88	42%	65%	83%
Female	91	76%	66%	33%
Total	179	59%	65%	58%

DISCUSSION

Although mean wing measurements of female common snipe from northwestern California averaged larger than males, differences were small. Moreover, much group overlap existed in these characteristics, which limited the ability to accurately distinguish sex. Because the 2-variable CDA misclassified approximately equal percentages of males and females (Table 3), measuring wing dimensions more precisely may refine group separation. Instruments with lower tolerances than the civil engineer's ruler may provide more precise and repeatable measurements and reduce group overlap due to the resolution of uncertain significant digits and rounding (Williams et al. 1984). However, sophisticated measurements may reduce efficiency and field application.

For common snipe migrating through and wintering in northwestern California, adding a variable and using CDA to maximize statistical differences increased predictive power over Whitehead's (1962)[3] technique. Investigating other morphometrics may reveal additional physical variation between sexes. For example, Hofmann (1987)[4] and Green (1991) explored combinations of bill and outer rectrix lengths. Unfortunately I did not retain rectrices. Combinations of quantitative and qualitative variables, such as wing coloration patterns, may also improve accuracy. However, additional variables may limit field application and large-scale population monitoring.

Whitehead (1962)[3] suggested that relative size differences between sexes might vary among North America populations. Supporting this assertion, mean 1st-secondary widths of females from Louisiana were 2 mm larger than males (Whitehead 1962), whereas females from northwest California were only <1 mm larger than males and sexes exhibited greater overlap. My results suggest that wing measures may vary more among populations than within and may not significantly differ between sexes within some populations. Consequently, a sexing technique that relies on subtle physical size differences of this highly monomorphic species may have most promise when developed for individual breeding or wintering populations.

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UNUSUAL PREDATORY BEHAVIOR OF A SOUTHERN SEA OTTER

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On January 30, 2003, a southern sea otter, *Enhydra lutris nereis*, was sighted killing common loons, *Gavia immer*, 50 meters (m) from shore and just north of the Del Monte Beach Townhouses on La Playa, Del Monte Beach, Monterey, California. Although past observations of sea otters feeding on birds have been reported, this particular incident was unusual because it did not appear to be related to feeding and the predatory behavior differed from previous observations.

Since 1969 there have been at least 20 reports of sea otters feeding on seabirds in the Monterey/Carmel area (Riedman and Estes 1988). The reports are concentrated in the Monterey harbor area, Stillwater Cove, and Point Lobos State Reserve. In these reported incidents Western grebes, cormorants, gulls, common loons, and surf scoters were taken and eaten. In 1986, six predations by the same male sea otter occurred at Whaler's Cove, Point Lobos, with five in March and one in April. This otter captured the birds by diving and grasping from underwater while the bird rested on the surface, similar to the way coastal river otters, *Lontra canadensis*, capture seabirds. Researchers that recorded these observations suggest that capturing a bird by grabbing it from under water while the bird floats on the surface takes planning and intelligence. Furthermore, they state that this is an example of sea otters learning a new behavior, one requiring skills quite different than those needed to capture slow moving or sessile invertebrates. The observation that follows is similar to the observations cited above in that birds are killed by a sea otter. More importantly, the present observation is dissimilar because the birds are not eaten by the sea otter and the manner in which the birds are killed differs from previous observations.

At 1530 hrs on 30 January 2003, a common loon was sighted approximately 50 m from shore in calm water off Del Monte Beach in the Monterey harbor area. The loon appeared to be in distress – thrashing in the water with feet, flanks, wings, and dorsal surfaces alternately visible. Examination through 10 x 40 Zeiss binoculars revealed that the loon was held to the chest of a sea otter. The otter rolled in the water with the bird, holding it with its forepaws. It appeared to wrestle with the loon, wrapping its body around the loon, tail and hind flippers flailing wildly. As the thrashing of the loon subsided, the otter rolled onto its stomach (ventral side) and held the loon underwater for approximately 3 minutes. During this time all that could be observed from the surface was the back of the otter. Then the loon surfaced, apparently unharmed, and attacked the otter by pecking at its head and neck multiple times. There was no noticeable

response from the otter. The loon then "ran" 5 to 6 m across the water, as if attempting to take off, then settled back on the surface. Within a minute the otter attacked the loon again, not from underneath as has been reported by Reidman and Estes (1990), but swimming on the surface on its ventral side. It rammed into the loon's side and grasped it with its paws. The loon exhibited less thrashing while being held this time. The otter rolled over and held the loon underwater longer than in the previous bout. After 5 minutes, the loon floated to the surface, motionless and dead, white ventral side up. The otter drifted 3 to 5 m away and rested on its back. The otter did not consume the loon after the attack. During this observation period, a second loon was observed floating dead, ventral side up, approximately 15 m farther out from the encounter just witnessed. At 1600 hrs the same otter attacked a third loon and repeated the killing behavior described above.

This otter had no identification tags and its nose was entirely black. The sex of the otter could not be determined. Typically, males are involved in the majority of seabird-eating reports (Reidman and Estes 1990). This incident does not appear to be an example of feeding behavior since the otter made no attempt to eat any of the three loons. Two days after this incident one intact and uneaten, dead, common loon was found on the same beach.

Of note also is the method of attack, which differs from previous reports. The otter did not dive and grab from underwater (Reidman and Estes 1990). Instead it stayed on the surface and swam rapidly, dorsal side up, ramming into the loon and grasping it. This "wrap around assist" is possible because of the body shape and flexibility found in mustelids (Powell 1982). Mustelids manipulate and position prey using their feet (Svendsen 1982) and kill by directing a bite to the back of the head or neck (Powell 1982). The latter behavior was not seen during this reported incident. If biting the neck or head occurred while underwater it could not be observed.

This observation could be an isolated case of a rogue sea otter exhibiting surplus killing. Surplus killing has been documented in many predator species and the Mustelid family is known to exhibit this behavior, although terrestrial mustelids usually cache the surplus. (Powell 1982, Svendsen 1982). Alternately, this observation could be related to a territorial struggle precipitated by limited food supply, disease and dementia, or some other environmental or ecological stressor.

Anecdotal observations of this kind should be reported. They add to the body of knowledge about this threatened species. This may be the first report of an unusual killing behavior by a sea otter involving a seabird in which the prey was not consumed.

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